Sky and TELESCOPE

New Zealand observatory

In This Issue:

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AUGUST, 1960
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SKY and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

Vol. XX, No. 2 AUGUST, 1960

CONTENTS

COVER: Towering over the dome of New Plymouth Observatory's 6-inch refractor is the volcanic cone of Mount Egmont on New Zealand's North Island. It was on the 8,260-foot dormant volcano's slopes that Rev. Oscar Blundell, a founder of the New Plymouth Astronomical Society and the observatory's first director, died in 1925 during a climbing expedition. Since 1920, this amateur group has played a leading role in both the observational and educational aspects of New Zealand astronomy. Taranaki "Herald" photograph. (See page 68.)

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LETTERS

Sir:

On page 431 of the May issue, mention was made of the extreme rarity of transits of Venus, the last such events having occurred in 1874 and 1882. I am very proud to say that I saw the passage of Venus across the sun's disk on December 6, 1882. At that time I was 11 years old, and living at Girard, Kansas. We smoked broken pieces of window glass over a coal-oil lamp, and I can remember Venus as a little black disk on the sun, no telescope being needed.

Nearly 71 years later, I observed the transit of Mercury on November 14, 1953, with a 6-inch reflector made by my son.

CHARLES E. HERRIMAN
320 S. Elmwood Ave.
Kansas City 24, Mo.

Sir:

As an amateur astronomer, I have spent nearly 10 years completing a lunar globe, using photographs of the moon from Mount Wilson and Palomar Observatories. The globe is 34 centimeters (about 13½ inches) in diameter, and shows 7,000 craters, of which some 400 are labeled. A photographic effect is achieved by shading, a silver-gray tone being used for the moon's far side, whose major features are taken from Russian Lunik pictures.

A mechanical device served to compensate for perspective foreshortening of the limb features, where the librational regions are distinguished by color. This globe will be printed in five colors, but the publisher has not set the date for the first edition.

ALFRED SCHLEGEL
Fr. Ebertstr. 35
Selb, West Germany

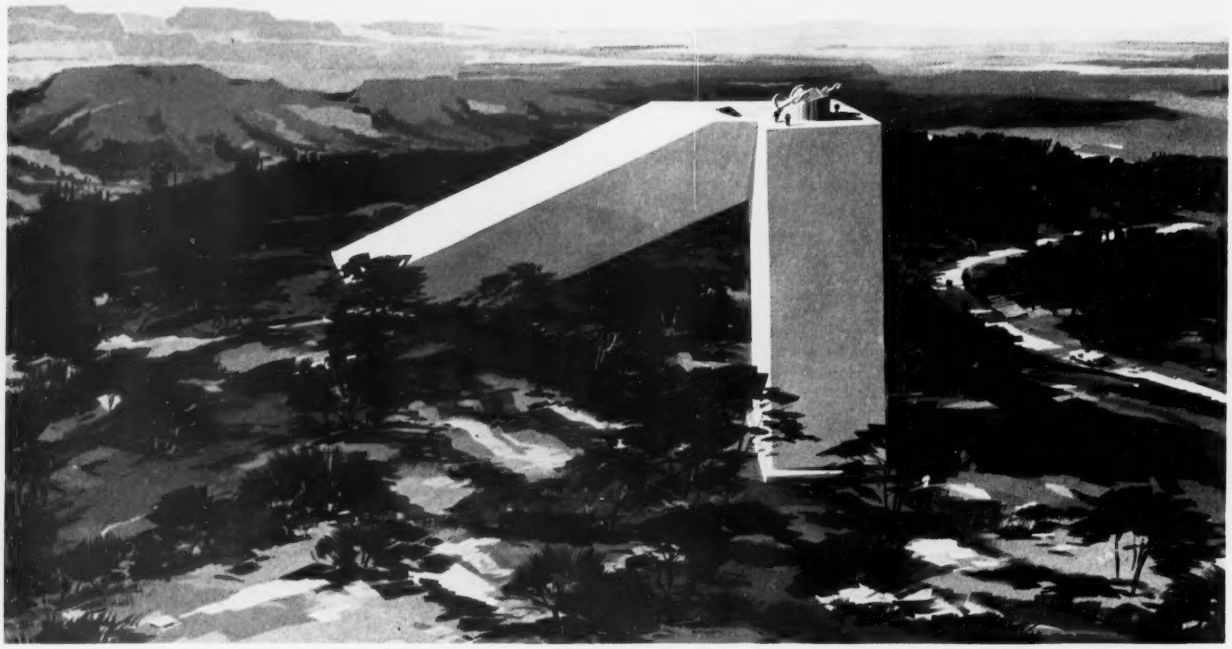
Sir:

Upon my recent arrival in France for a prolonged stay, I sought out other amateurs by visiting the Société Astronomique de France. Its headquarters are in a massive old building at 28 Rue Serpente in Paris. The group was organized in 1887 by Camille Flammarion, and now has several thousand members.

At Paris there are two refracting telescopes, of 6-inch and 8½-inch aperture. One is used for observing at public nights on Tuesdays and Saturdays, and the other is reserved for double star studies.

Mme. Gabrielle Flammarion, widow of the founder, actively runs the society's affairs as secretary-general, although she is well advanced in years. It has been her annual custom to invite special guests to her chateau in Juvisy on the anniversary of her husband's death in June, 1925. This is a simple but impressive ceremony, to which my family and I were graciously invited, along with 75 French astronomers and friends.

WILLIAM F. LOOMIS
14 Place Vendome
Paris 1, France



An artist's conception of the structure, some 100 feet high, that will house the world's largest solar telescope. At the top of the tower, an 80-inch heliostat mirror will reflect sunlight southward along the slanting polar-axis shaft, to a 60-inch long-focus mirror nearly 500 feet away. Compare this picture with the diagram on page 66.

The Large Solar Telescope at Kitt Peak

ROBERT R. MCMATH and A. KEITH PIERCE, *Kitt Peak National Observatory**

IN THE ENTIRE WORLD there are some 70 solar telescopes, according to R. Coutrez' listing, ranging up to an aperture of about 24 inches and a maximum prime focal length of 150 feet. To these we might add many of the large stellar telescopes, reflectors and refractors, that have been used briefly in solar work.

For example, the early research of G. E. Hale and F. Ellerman was carried out with the Rumford spectroheliograph attached to the 40-inch refractor of the Yerkes Observatory, and H. H. Plaskett used the 72-inch Victoria reflector in his studies of solar granulation. But in spite of this dual use of some telescopes for solar as well as stellar work, two more-or-less distinct types of instrument have evolved.

This has come about because of the great differences in the auxiliary spectrographic equipment required, for the sun provides 10 billion times more light than the brightest star in the night sky! With such an abundance of available light, there is little reason to utilize the very low-dispersion spectrographs of stellar instruments on solar problems. On the other hand, for the moment there is no possible way to use a spectroheliograph or a Lyot filter to examine the surface of a more distant star than the sun.

Hence, there is wide divergence in both form and function of solar and stellar telescopes. However, as mentioned above, a stellar instrument can be used for some solar research, and a telescope designed to study the sun may be satisfactory for work on certain stars. In particular, the 60-inch solar telescope and its powerful spectrographs, now under construction at Kitt Peak National Observatory, can be employed to study stars brighter than the 6th magnitude.

Early in 1954, the National Science Foundation appointed an ad hoc advisory panel composed of I. S. Bowen, Leo Goldberg, B. Strömgren, Otto Struve, and A. E. Whitford, with the senior author of this article, Robert R. McMath, as chairman. The panel was to examine the United States' need for large telescopes. After a study of the existing observing facilities, these astronomers advocated immediate construction of 36-inch and 80-inch photoelectric stellar telescopes, and the world's largest solar instrument, which is to have a 60-inch aperture and 300-foot focal length.

Following a site survey, Congress voted funds to the National Science Foundation for the construction of these instruments on Kitt Peak in Arizona. The new national observatory was dedicated on March 15th, and the 36-inch reflector is already in operation, as described in the May issue of this magazine.

A solar telescope is designed around its optics, starting with the grating of the principal spectrograph. The grating's resolving power and dispersion must be equated to the scale and resolution of the photographic plate (or image orthicon, or exit slit for monochromatic work), to determine the focal length of the spectrograph and its focal ratio. To conserve light, we must make the latter equal to the focal ratio of the spectrograph, but fixing the actual size of the telescope requires a further consideration — the research program.

Work on the spectra of solar granules, on the physical structure of sunspots and their associated magnetic fields, requires considerable image size. Past experience has shown that the optimum image of the sun should be approximately a yard across. Therefore, we have selected a 300-foot focal length to obtain an image that is 34.08 inches in diameter when the earth is at perihelion, early in January each year, and 33.02 inches at aphelion in July. Under proper seeing conditions with this

*Operated by Association of Universities for Research in Astronomy, under contract with the National Science Foundation.

scale, detailed microphotometry of spectra of granules one second of arc in size (0.44 millimeter) and smaller is feasible and precise.

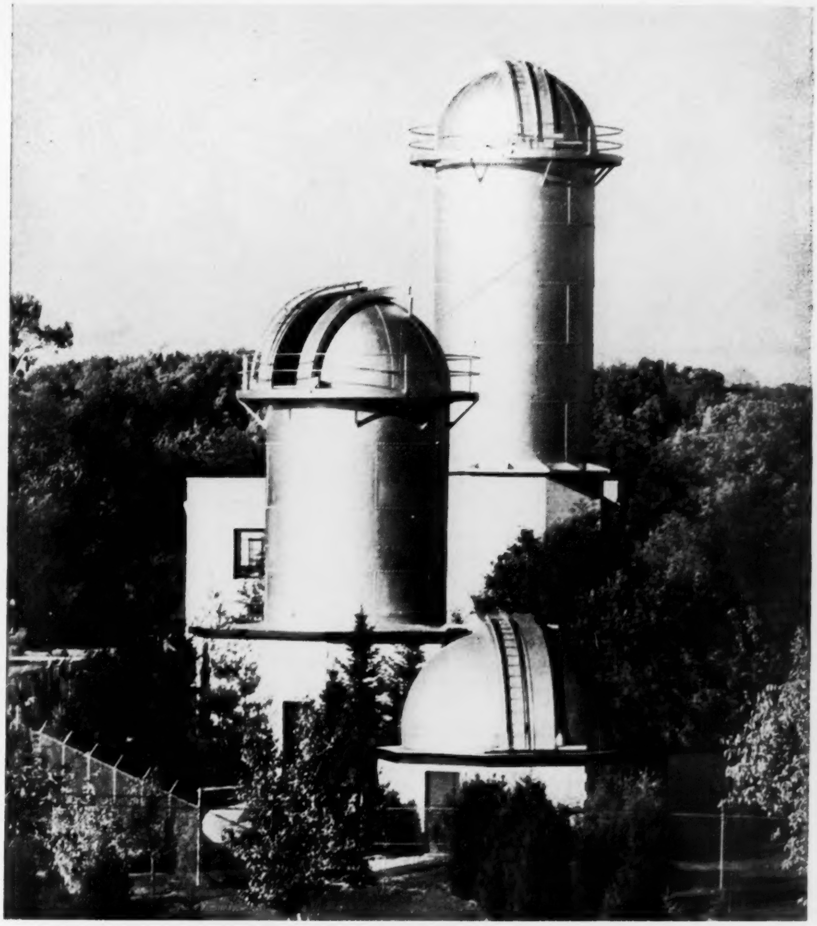
At present, there are available for the solar telescope two quartz disks suitable for optical mirrors 60 inches in diameter and nine inches thick. Quartz is desirable for solar studies because it has a much lower coefficient of thermal expansion than glass does. These blanks were the final efforts of A. L. Ellis and E. Thomson, at the Lynn plant of the General Electric Co. in 1931, to prepare quartz disks up to 200 inches in size for the 200-inch Palomar Observatory reflector. The story, so well told by Helen Wright in her book *Palomar*, closes:

"At that time (1931) the 60-inch disks were considered useless for astronomical purposes. For many years after the work ended, they remained at the General Electric plant. Nobody wanted them, nobody cared. Recently, however, Robert McMath of the McMath-Hulbert Observatory at Pontiac, Michigan, who has done remarkable work making motion pictures of the sun, remembered the disks. Perhaps, as Hale had suggested, they might be usable for solar work. Perhaps he could use them for his work in the infrared. Today the disks are in Ann Arbor. Perhaps, after all, they may be useful and those years of 'arduous' work will not be wasted. If so, in the light of their original fantastic cost [$600,000], they will be the most valuable mirrors in use anywhere in the astronomical world."

The 60-inch quartz blanks will be used in the Kitt Peak solar telescope until suitable materials can be found for the final optics that require blanks 48, 60, and 80 inches in diameter.

Details of many optical arrangements for the solar telescope were studied. Basically, there are three ways to feed light to our 60-inch image-forming mirror. First, the mirror may be pointed directly at the sun. Second, a single mirror mounted as a *heliostat* can send sunlight either toward the south pole or the north pole of the sky. Third, two mirrors can be used in the combination called a *coelostat*, the second mirror reflecting light in any fixed direction — usually horizontally or vertically downward as in a tower telescope.

In the first arrangement, like that of the usual reflector feeding light to a spectrograph at the coude focus, the shadow of the Cassegrainian secondary produces a broadened diffraction pattern that lessens contrast in the primary image; in the spectrograph it fills the cores of the Fraunhofer dark lines with diffracted light. However, of even greater importance is the possible impairment of the seeing by so great a concentration of heat energy in the convergent beam of a short-focus reflector. In some instruments of this kind, water cooling of the secondary mirror is necessary.



Famous towers to the sun at the McMath-Hulbert Observatory as they appeared about two decades ago (before the trees grew high). The cupolas on the 50- and 70-foot towers contain coelostats that direct sunlight to spectrographs and spectroheliographs. University of Michigan photograph.

For a very large instrument, the principal advantage of the heliostat over a coelostat is that the former requires but a single optical flat. Hence, the cost is less: there is a light loss at only one reflection instead of two; the incident light remains at a constant angle to the mirror, the reflected beam's ellipticity remaining constant for a day's observation; the polarization of the reflection stays the same; and there is no "noon shadow" of one mirror on the other, as occurs with a coelostat.

The disadvantages of the heliostat are twofold. It causes the image to rotate once in 24 hours, whereas the coelostat provides a nonrotating field of view. The angle between the incident and reflected light is in general greater than in the optimum position for the two mirrors of a coelostat. But these two defects are far outweighed by the advantages stated above.

Inner Telescope Structure

A heliostat instrument was therefore chosen, and the following design criteria set up:

1. The 80-inch heliostat mirror was to be 100 feet above the ground, supported on an inner structure and surrounded by a wind shield.

2. When the supporting tower deflected because of the effects of a wind up to 25 miles an hour, the displacement of the sun's image was not to exceed one-third of a second of arc. (This is less than 1/60 inch at the end of an optical path 780 feet from the heliostat!)

3. All exterior surfaces exposed to sunlight were to have their temperatures controlled, in order to avoid the effects of thermal changes on the optical path.

During the fall of 1957, Detroit engineer W. Zabriskie prepared for the authors detailed drawings of three possible designs. In one the inner telescope structure supporting the heliostat was fabricated of standard H-beams; in another it consisted of large tubular sections; while in the third it was to be made of concrete.

In these three designs, the inner telescope was an immense vertical triangle with its hypotenuse along the polar axis, appearing like the gnomon or index of a sundial. The upper end carried the heliostat, while the 60-inch parabolic mir-


On March 15th this year, while Kitt Peak's dedication ceremonies took place nearby, this bulldozer began leveling operations at the solar telescope's location on the south ridge. The 60-foot site-testing tower is at the left, and to the right, the rounded dome of distant Baboquivari Peak.

ror was to be placed at the south end at ground level. From there the light was reflected up the polar axis for 180 feet, but 1½ degrees off-axis, to a flat and then vertically 120 feet downward to an underground spectrograph room. A water-cooled outer skin acted as a wind screen.

A year later, when further design work was started, the Association of Universities for Research in Astronomy (AURA) asked the Chicago firm of Skidmore, Owings, and Merrill to review all possible structures (including those already proposed) that would satisfy the optical requirements. This study, directed by W. Dunlap and S. Sachs, developed a most unusual building, consisting of a tapered cantilevered tower projecting from the ground toward Polaris and a similar inner section supporting the heliostat — an extreme case of the leaning tower of Pisa.

We abandoned this design for the less costly and more stable structure illustrated here, the heliostat being supported on a vertical concrete cylinder 26 feet in diameter with walls four feet thick. Light from the heliostat is directed southward, along the polar axis, about 480 feet to the 60-inch off-axis paraboloid. From here the light is sent, at an angle of about 1¼ degrees to the primary beam, to the 48-inch diameter flat that directs light vertically downward to the focus at the head of the vacuum spectrograph.

A steel track of 12-foot gauge, extending nearly one-tenth of a mile from the heliostat to the 60-inch primary mirror, carries all the mirror mountings. It will provide a convenient means of handling each mirror mounting in the initial assembly, as well as whenever the mirrors are to be washed or aluminized. The aluminizing room, with a 15-ton capacity overhead bridge crane, is located just south of the observing room.

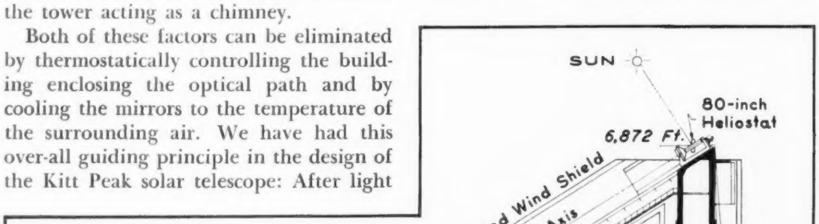
Outer Telescope Building

Optical definition of the sun's image formed by a tower-type telescope is often very good when the dome is first opened, but within a few minutes the seeing markedly deteriorates. Since this phenomenon is more or less independent of the time of day, it is a characteristic fault of the instrument, though we are not certain how much of the trouble is caused by warm air currents rising from the mirror surface itself and how much is due to the tower acting as a chimney.

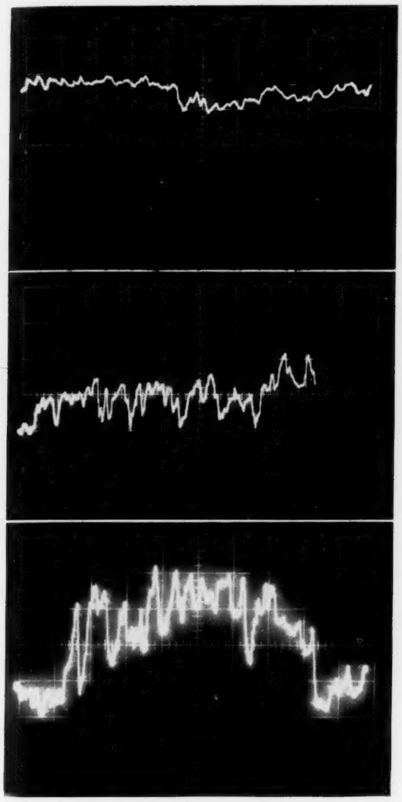
Both of these factors can be eliminated by thermostatically controlling the building enclosing the optical path and by cooling the mirrors to the temperature of the surrounding air. We have had this over-all guiding principle in the design of the Kitt Peak solar telescope: After light travels through the atmosphere the quality of the seeing should not be destroyed in the last few hundred feet near the focus.

At many solar observatories, such as Meudon in France and Cambridge in England, the optical path is horizontal and only six to eight feet above a grassy ground surface. The many superb spectra and spectroheliograms procured at these places, particularly in the early morning before the ground becomes appreciably heated by the sun, attests to the excellent seeing, both external and internal, of those solar instruments. However, micrometeorological studies have shown that temperature fluctuations decrease with height, so still better results might be obtained by going higher. In 1904 Hale wrote:

"Everyone who has noted the heated air above the surface of the ground will wonder, in considering the effect of such disturbances upon solar observations, whether these disturbances rise to a great height. A casual observation is sufficient to show that the disturbance decreases rapidly in passing upward from the ground, but it is, of course, quite impossible to determine by means of the unaided eye the probable effect of this disturbance on telescopic observations. We have accordingly made many observations of the sun with the 3¼-inch telescope supported in a pine tree at heights above the ground ranging from 20 to 80 feet. The results of these observations clearly indicate that a telescope employed in solar work should be mounted as high above the ground as circumstances warrant. At the lower elevations in the tree the advantage over positions still nearer to the ground was sometimes not appreciable; but at a height of 80 feet above the ground the improvement in definition was very distinct. Probably this is one of the reasons why the solar definition with the 40-



Part of the Kitt Peak solar telescope will be far above ground, part well below.



Air-temperature fluctuations measured at the solar telescope site (pictured opposite) on July 16, 1959. The apparatus was suspended 1½, 10, and 55 feet above the ground (bottom to top), and the observations were made at 11:20, 11:30, and 11:40 a.m., Mountain standard time, respectively. The grid scale on the cathode-ray tube is in centimeters, the horizontal sweep rate being five seconds per centimeter for a total sweep time of up to 50 seconds. Vertically, each centimeter mark is for 1.4 degrees centigrade, or about 2½ degrees Fahrenheit. The thermistor element was directly coupled through a preamplifier to the oscilloscope tube. Kitt Peak Observatory photograph.

inch Yerkes telescope averages considerably better than we expected it would, for with this telescope the object-glass is over 70 feet above the ground."

Of course, placing the objective so high is costly, primarily since we must solve the engineering problems relating to stability. For a freely standing tower of uniform cross section subjected to a uniform wind load, the deflection at the top varies as the third power of the height. But the situation is more critical when mirrors are employed, for the deflections caused by rotational motion are amplified two times by reflection. (A simple translational motion is of no consequence for a plane mirror.) It is evident that, to avoid excessive costs, the objective's height must not be made 200 feet if 100 feet will do. The choice will depend upon the magnitude of the thermal fluctuations at various heights above the ground level of the observing site.

We have carried out at Kitt Peak the first phase of a series of experiments with equipment designed and constructed by W. C. Livingston. These show, in a spectacular manner, an exponential decrease of temperature fluctuations with height. Observations have been made on quiet days at altitudes ranging from zero to 180 feet, using a small temperature-sensitive thermistor suspended with its preamplifier unit from a tower or balloon. The picture shows that short-period temperature fluctuations decrease from about three degrees centigrade near the ground to less than 0.4 degree at a height of 55 feet. In another experiment, they decreased to about 0.2 degree at 180 feet. Considering this information and past experiences with solar telescopes, we adopted 100 feet as a minimum height suitable for the entrance port of our instrument.

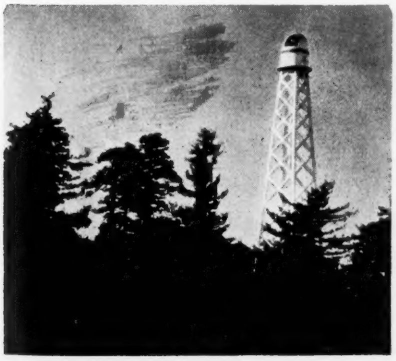
Since we propose to cool all surfaces to the ambient air temperature, we have investigated several coatings. Tests show that black surfaces exposed to sunlight absorb about one horsepower per square yard, heating up to around 55 degrees Fahrenheit above the surrounding air temperature. An aluminum-painted surface warms up 30 degrees, about the same as bright polished aluminum or chromium. These metallic surfaces may absorb only 15 or 20 per cent of the incident energy, but their emissivity is very low, and their ability to radiate energy at a low temperature in the infrared is extremely poor — hence they get hot.

It has been found that a surface painted with pure titanium dioxide pigment in a glyptal vehicle warms up in full sunlight only 10 to 15 degrees Fahrenheit. This is our best result so far. The low temperature rise occurs because this paint is effectively black in the infrared. When exposed to the blue sky, which has an effective infrared temperature of about −20° to −40°, the titanium dioxide has a very cold element of large extent to radiate to, and therefore remains cool.

Recent experiments have been conducted for us by Mr. and Mrs. Raymond Bliss, of the University of Arizona's solar energy laboratory. They find that the cooling load for the solar telescope's outer skin, with its 34,000 square feet of area, requires only 14 tons of refrigeration if painted white with titanium dioxide, whereas if painted black the cooling load would be five to 10 times as great.

A refrigerating plant will be located 200 feet north of the telescope. Refrigerant, water with antifreeze, will be carried in underground pipes to the telescope and circulated through copper tubes imbedded in the copper skin. This additional cooling will bring the skin temperature to the surrounding air temperature.

(To be continued)



At the right is an unusual view up the inside of the 150-foot solar telescope tower at Mount Wilson Observatory in California. The tower itself, seen from a distance, is pictured at the left below. For the interior view, the camera was pointed nearly vertically, alongside the corrugated tube that contains the optical path and dominates the lower part of the picture. Beside it is the open elevator shaft leading to the top of the tower, where a two-mirror coelostat is located. Photographs by Charles H. Coles.

Amateur Astronomers

New Zealand Observatory Marks 40th Anniversary

BECAUSE of limited professional equipment in New Zealand, amateur astronomy plays an important role in our country. For 40 years, the New Plymouth Observatory, manned by amateur astronomers, has assisted in this endeavor.

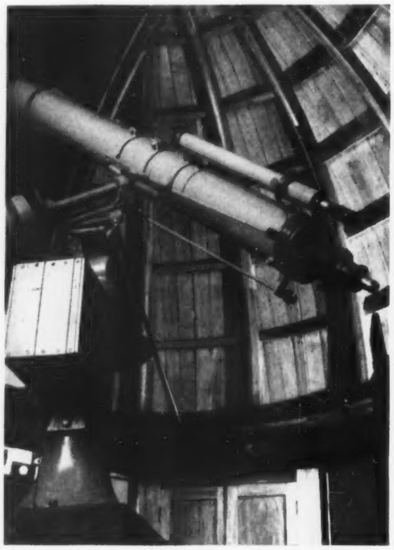
Despite modest equipment and a small number of observers, the installation has gained scientific recognition, being listed in various ephemerides. Its position is longitude −174° 04′ 26″.6, latitude −39° 03′ 45″.2.

Enthusiasm for the stars led Rev. Oscar Blundell to initiate the New Plymouth Astronomical Society in 1919. An inaugural meeting was held on July 3rd, after which the group quickly moved toward establishing an observatory, and by October of that year work on it had begun.

The principal instrument is a 6-inch Alvan Clark refractor. It has been used mainly on occultations, variable stars, and sunspots. One night each week is set aside for the public, and more than 25,000 persons have visited the observatory since it was opened.

The bulk of the observing work during the 40-year period has been by F. J. Morshead, who was observatory director from 1925 to 1958 and a former president of the Royal Astronomical Society of New Zealand, and by D. Wilkinson, who concentrated on variable stars. Mr. Morshead spent many hours sweeping for comets, and in November, 1923, made an independent discovery of one. The object was entered in the observatory's logbook as Morshead's comet, but later information disclosed that it had been seen earlier in Europe.

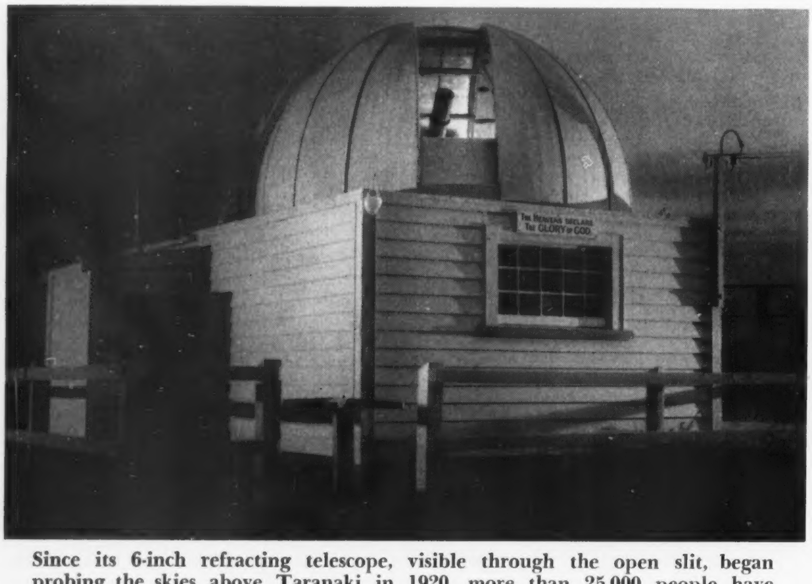
Of particular pride to our society was



In 1921 the original mounting of the 6-inch telescope was replaced by the equatorial one shown here, which has a clock drive. The photographs on this page are by G. Fergusson.

Murray Geddes, who received his first training in astronomy at our observatory. In June, 1932, while observing from central Otago in New Zealand's South Island, he discovered a comet on his first night of sweeping. For this, he was awarded the medal of the Astronomical Society of the Pacific and Australia's Donovan prize and medal. Unfortunately, he died while on active duty in the navy during the second world war.

At present, membership in the society totals 55. Besides having monthly lectures, our society writes a weekly astronomical column for the local daily newspaper, the Taranaki *Herald*. From August 22nd to 27th, we are planning a planetary week, with special observations and lectures on Jupiter, Saturn, and Mars.



Since its 6-inch refracting telescope, visible through the open slit, began probing the skies above Taranaki in 1920, more than 25,000 people have visited the New Plymouth Observatory on Marsland Hill.

S. L. DICKSON
5 Holsworthy St., Vogeltown
New Plymouth, New Zealand

WESTERN AMATEURS PROGRAM

Walter J. Krumm, chairman of the Western Amateur Astronomers, has released the following program for the WAA convention in San Jose, California, at the end of this month. Convention headquarters will be at the Hotel Ste. Claire, and meeting sessions in the San Jose municipal auditorium.

Tuesday, August 23rd

All day. *Western Satellite Research Network session.*

Evening. *Satellite observing.*

Wednesday, August 24th

All day. *Association of Lunar and Planetary Observers session.*

6:30 p.m. *WAA business meeting and dinner.* Hotel Ste. Claire.

Thursday, August 25th

All day. *WAA session.* Main speaker, H. Julian Allen, assistant director, Ames Research Center, "The Physics of Meteors."

Evening. *Visit to Lick Observatory.* Tour of the facilities, including inspection of the 120-inch telescope.

Friday, August 26th

9:30 to 11:30 a.m. *WAA session.* Morrison lecture by G. Swamp, "Radio Astronomy and the Work at Stanford University."

12:30 p.m. *Field trip to Ames Aeronautical Laboratory and Stanford's radio astronomy research installation.* By chartered bus.

7:30 p.m. *Star party.* Santa Clara County Fairground. Astronomical films if sky is overcast.

Saturday, August 27th

All day. *WAA session.* Morrison lecturer, Dr. William P. Bidelman, Lick Observatory, "Spectroscopy, a Key to the Stars." Robert M. Crane, Aero-Thermodynamics Division, Ames Research Center, "The Orbiting Astronomical Observatory."

6:30 p.m. *Banquet.* Main speaker, Dr. Alfred J. Eggers, Jr., Ames Research Center, "Manned Spaceflight." Presentation of the G. Bruce Blair award to David Barcroft of Madera, California.

FARMINGDALE, NEW YORK

The Long Island Students of Astronomy meet twice monthly, the second and fourth Monday from 9 to 10:30 p.m., at 20 Yoakum Ave., Farmingdale, N. Y. Further information is available from W. Huebner, 69 Duane St., Farmingdale.

Astronomical League Convention Program

HIGHLIGHT of the coming Astronomical League convention will be an all-day bus tour of astronomical and historical sites in the Philadelphia, Pennsylvania, area on Sunday, September 4th.

Starting at 9:30 a.m. from convention headquarters at Haverford College, the delegates will visit the Franklin Institute and its Fels Planetarium, then drive to Barrington, New Jersey, where the Edmund Scientific Co. will serve a steak dinner. Crossing over to Yorklyn, Delaware, they will inspect Spitz Laboratories, where two of its latest planetarium projectors will be displayed. A buffet supper is also to be given by that company. The final stop will be at Sproul Observatory in Swarthmore, Pennsylvania, world famous for its work on star distances and discoveries of invisible components of binary stars. The bus fare is $5.00, with the meals being donated by the respective hosts.

The convention will open at 1 p.m., September 3rd, with a general session, followed by one for junior astronomers. That evening a program entitled "15 Photoelectric Amateurs" will be held at the Flower and Cook Observatory in Malvern, Pennsylvania. One mile away, there will be open house at Villanova Observatory. For those who wish to remain in Haverford, the college's Strawbridge Memorial Observatory is also having a star party.

Monday will be devoted to amateur papers. The morning session is for the Association of Lunar and Planetary Observers, the afternoon for instrumentation. Dr. Louis C. Green, director of Haverford's observatory, will be principal speaker at the honor dinner that evening. His topic is "Rockets, Satellites, and the New Astronomy."

Housing for the delegates at Haverford College, which is just outside Philadelphia, will become available on Friday afternoon, September 2nd, nightly rates being $3.00 a person. Registration until August 15th is $1.00; after that date, $1.50. The honor dinner on Monday will cost $4.00. Reservations should be sent to General Convention Astronomical League, Franklin Institute, Philadelphia 3, Pa.

Program time may be secured from the persons listed on page 477 of the June issue. Exhibit information is available from David Claus, 75 S. Main St., Mullica Hill, N. J.

EDWIN F. BAILEY
Franklin Institute
Philadelphia 3, Pa.

AAVSO SPRING MEETING

ABOUT 80 persons attended the 49th annual spring meeting of the American Association of Variable Star Observers at the American Museum-Hayden Planetarium in New York City, May 27-28. The planetarium and the Amateur Astronomers Association were hosts.

Mrs. Margaret Mayall, AAVSO director, announced that 30,612 observations had been received and recorded during the first five months of this year. These include observations from South America, South Africa, Europe, Australia, and India, as well as the United States. Since October, 1959, 36 new members have joined the organization.

Harry Bondy, chairman of the solar committee, reported that the flare patrol, which also operates on a world-wide basis, had gathered data on almost 1,200 sudden enhancements of atmospherics, adding that the group had contributed about 40 per cent of all SEA's published by the National Bureau of Standards. A record number of observed occultations — 82 from 24 observers — has been received by Roy Seely, in charge of the occultation committee.

Among the talks presented were: Patrick Rizzo, check list for locating variable stars; William H. Glenn, moon-shadow observations during the October 2, 1959, solar eclipse; Victor Gogolak, photometric observations of the total eclipse; Ralph Buckstaff, the December 3, 1959, white solar flare; Mr. Bondy, white solar flares as rare phenomena; Richard Hamilton, the Stamford, Connecticut, Observatory; Mrs. Florence Glenn, novae; Kenneth Weitzenhoffer, radio telescopes. Color slides were presented by Albert Ullman. In addition, the delegates were given a special demonstration of the planetarium's new Zeiss projector.

MRS. JANE DOUGLAS
160 W. 73rd St.
New York 23, N. Y.

NEW JUNIOR GROUPS

There are 10 amateurs in the Astronomical Society of West Lake County in Illinois. Vianna W. Biehl, Rte. 4, Box 196, Lake Villa, Ill., is the president.

ALAMOSA, COLORADO

Ten adults and five juniors comprise the Sky Valley Astronomical Society. Interested persons should contact Danny G. Johnson, Box 402, Alamosa, Colo.

FT. WAYNE, INDIANA

The Ft. Wayne Astronomical Society will hold its third annual astronomy exhibit on August 12-13 at the Conklin pavilion in Shoaff Park, northeast of Ft. Wayne, Indiana. Among the many displays that have been made by amateurs in the 75-member club are an orrery, a Foucault pendulum, and a moon model fashioned from a 10-foot-diameter balloon. Weather permitting, about 25 telescopes are to be set up for views of astronomical objects by the public. Last year's show attracted about 3,000 persons.

+++ Amateur Briefs +++

The back cover of the National Capital Astronomers' 1960 directory has a moon map by H. P. Wilkins showing objects near the Straight Wall. The Washington, D. C., group's booklet lists names of members, their addresses, and telephone numbers, as well as officers and committees.

Astronomy and affairs of heart. Two pairs of amateurs have decided to share their telescopes through life. The recently married couples are Jan Fultz and Noel Gutry of the Columbus (Ohio) Astronomical Society, and Mary Churns and David McConnell of New York's Amateur Astronomers Association.

George and Antony Doschek have given a Spitz A-2 planetarium to their society, the Amateur Astronomers Association of Pittsburgh. The projector is located at the Allegheny Observatory, where it will be used to supplement the group's observing sessions.

The Amateur Telescope Makers of Boston are taking no chances on bad weather interfering with their summer star parties. The club schedules two dates for each biweekly session; if the first is rained out, the group meets on the second night.

Work was started in June on the Indiana Astronomical Society's observatory at Philadelphia, Indiana. A roll-off roof will be utilized until sufficient funds are raised to complete the dome.

According to *Skyward,* monthly newsletter of the Montreal Centre, Royal Astronomical Society of Canada, the group "now has its own amateur radio license and has been given the call letters VE2RAM — for Royal Astronomical, Montreal. VE2RAM — the First Point in Aries!"

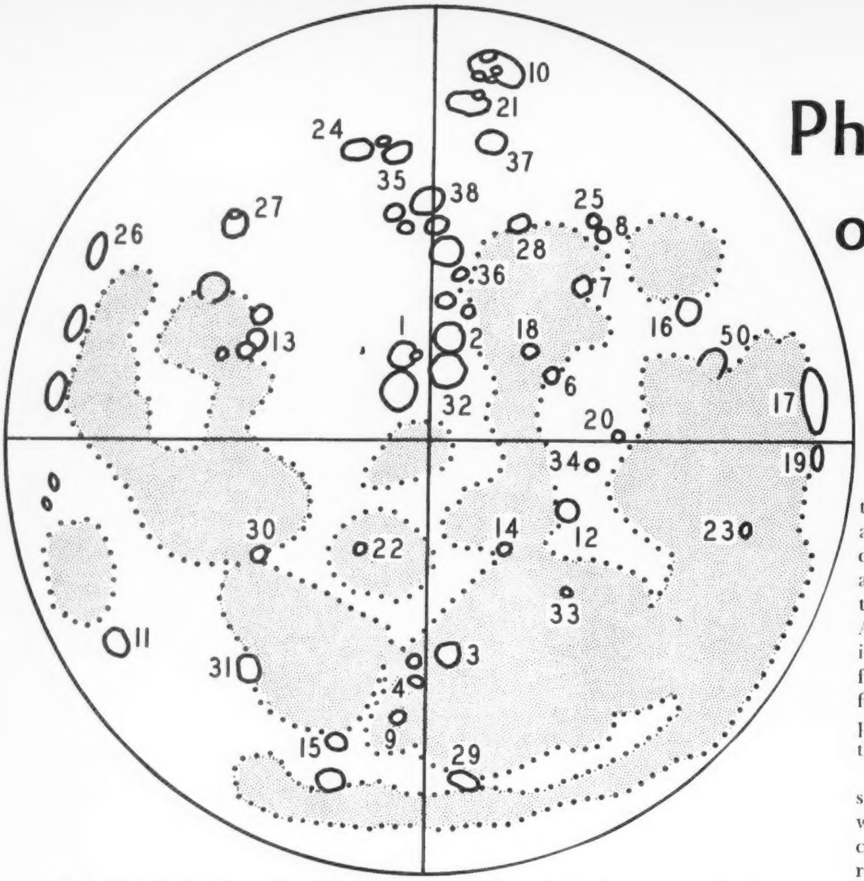
When a local newspaper phoned the Astronomical Society of Harrisburg, Pennsylvania, for the title of the talk to be given by guest lecturer Dr. Carl A. Bauer of Pennsylvania State University, it was inadvertently told, "The Abode of the Lost Planet." The correct title actually was "Bode's Lost Planet."

Anniversaries. The 15-member Vienna Astronomical Society in West Virginia recently marked its 10th birthday; the Grumman Astronomical Society of Bethpage, New York, its second.

The Amateur Astronomy League of Eugene's *Spectrum* is also serving as the official publication for the Rogue Valley Astronomer's Club in Grants Pass, Oregon. Meeting notices and special events of both societies will be published monthly.

Beginning observers who are interested in making detailed and serious studies of the planet Jupiter should contact the new Jupiter recorder of the Association of Lunar and Planetary Observers, Philip R. Glaser, 400 E. Park Ave., Menomonee Falls, Wis. The ALPO also wishes to cooperate with foreign amateurs and groups in observations of the giant planet.

H. M. C.



Van Diggelen's chart shows the 38 craters whose floors he measured photometrically: 1, Albategnius; 2, Alphonsus; 3, Archimedes; 4, Aristillus; 5, Billy; 6, Bonpland; 7, Bullialdus; 8, Campanus; 9, Cassini; 10, Clavius; 11, Cleomedes; 12, Copernicus; 13, Cyrillus; 14, Eratosthenes; 15, Eudoxus; 16, Gassendi; 17, Grimaldi; 18, Guericke; 19, Hevelius; 20, Landsberg; 21, Maginus; 22, Manilius; 23, Marius; 24, Maurolycus; 25, Mercator; 26, Petavius; 27, Piccolomini; 28, Pitatus; 29, Plato; 30, Plinius; 31, Posidonius; 32, Ptolemaeus; 33, Pytheas; 34, Reinhold; 35, Stöfler; 36, Thebit; 37, Tycho; 38, Walter.

Photometry of the Moon

Otto Struve
*National Radio Astronomy Observatory**

WITHIN the next few years, there will doubtless be many attempts to photograph the moon from camera-carrying space vehicles. These pictures should ultimately show much smaller details than terrestrial telescopes can, and will be used to study the structure of the lunar surface prior to the first landings of instruments on an extraterrestrial body. Robert Jastrow of the National Aeronautics and Space Administration recently pointed out, ". . . A growing body of scientific opinion holds that the moon will in many ways more richly reward the effort to reach it than will either Mars or Venus."

However, these prospects increase the need for astronomical studies of the moon by more conventional methods. Much information about the lunar surface must be gathered, so that its exploration by instrumented space probes can be properly planned. For example, we would like to learn beforehand about the texture of the surface, from measurements of the brightnesses of different areas under varying illumination.

In this respect, a major addition to our knowledge has recently been provided by J. van Diggelen, of Utrecht Observatory in the Netherlands. His investigation of the photometric properties of the lunar surface is based primarily upon a series of photographs of the moon made in 1946 by M. Minnaert with the 40-inch refractor at Yerkes Observatory.

Five of the best of these negatives, taken at different phases of the moon, were selected by van Diggelen, who measured on them the surface brightnesses of the floors of the 38 craters indicated on the chart. Because of the 40-inch telescope's working schedule at that time, all of the pictures were obtained after full moon, and hence he could not measure on every plate some of the craters located in the moon's western hemisphere.

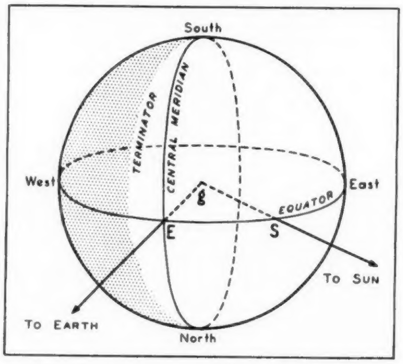
By means of photometric calibration scales on each plate, it was possible to convert the degree of blackening of particular areas into the corresponding relative surface brightnesses. Then all the photographs were tied into one photometric system, enabling the Dutch astronomer to derive for each lunar area a *lunation curve*, or plot of intensity versus phase angle.

The latter quantity is the angle **g**, at the center of the moon, between the sun and the earth, and is indicated in the diagram. Otherwise said, it is the arc along the moon's surface from the subterrestrial point **E** to the subsolar point **S**. Accurate computation of the phase angle is complicated by lunar librations. But for our general understanding, it is sufficient to assume that the subterrestrial point is always very close to the center of the moon's disk.

Immediately after new phase, when the sun's rays first illuminate the moon's western limb, the subsolar point is located about 180 degrees from the subterrestrial one. As the lunar crescent waxes, the subsolar point shifts from west to east, almost along the moon's equator, until at first quarter it is about 90 degrees from the subterrestrial point. At full moon, the two points nearly coincide, so the phase angle is approximately 0°. At third quarter, corresponding to phase angle 90°, the subsolar point is at the eastern edge of the moon and the terminator passes through the subterrestrial point. By convention, the phase angle is regarded as negative before full moon and positive afterward.

Taken as a whole, the moon's brightness changes greatly with phase angle.

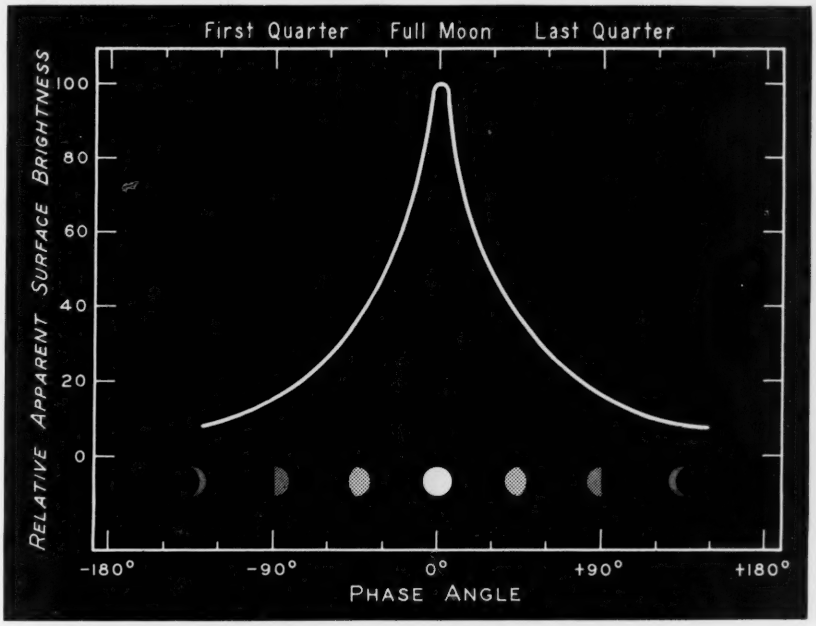
*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.



The moon is several days after full in this simplified diagram, where E and S are the subterrestrial and subsolar points, respectively, and g is the phase angle.

For instance, at first and last quarters, when the illuminated area that we see is half that of the full phase, the moonlight falling on the earth is only about one ninth as intense. It is evident that the apparent brightness of the moon's surface diminishes far more rapidly than its illuminated portion decreases in area as it changes from full moon to a crescent.

Van Diggelen has computed the lunation curve shown here, for the average apparent brightness of the lunar surface that is in sunlight. To his original chart we have added representations of the corresponding phases, the full moon being shown white, as its surface radiance has been taken as 100 per cent for the purposes of this graph. Van Diggelen computed this curve from one obtained photoelectrically in 1953 by G. Rougier at the Strasbourg Observatory that showed how the light from the whole moon changed with phase. The Dutch astronomer next compared with his curve the average surface brightness he measured on each of the Yerkes photographs.

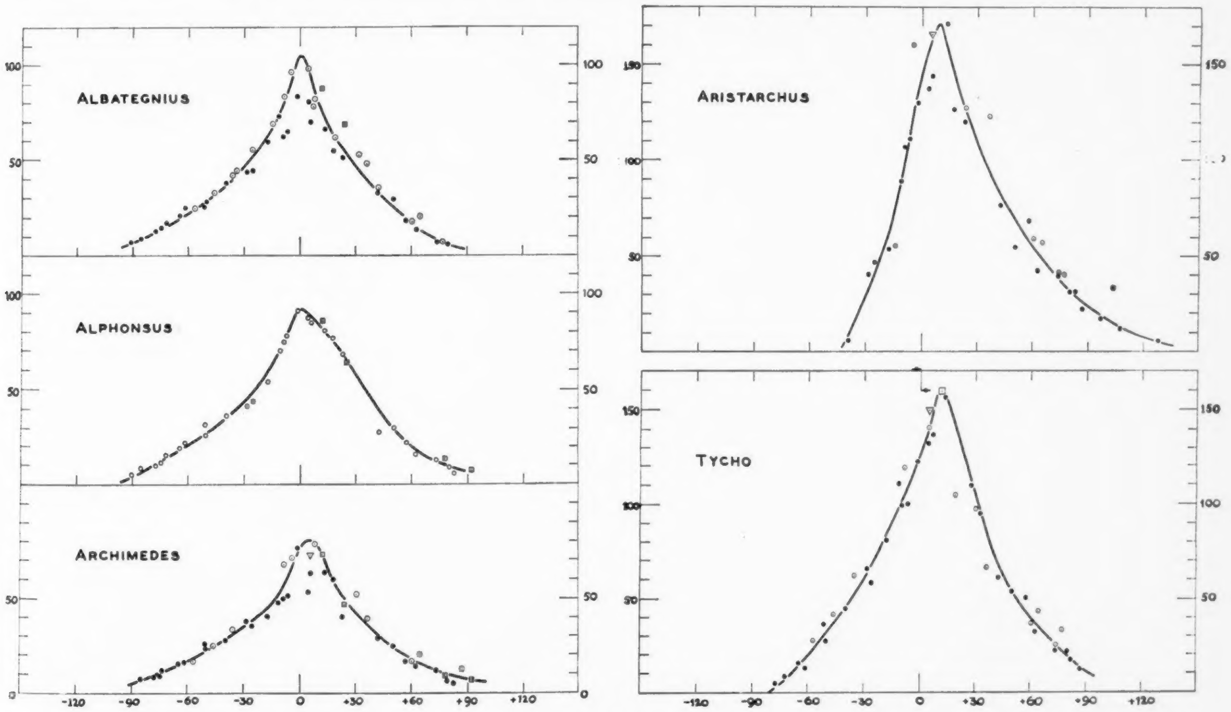


Surface brightness, averaged over the entire illuminated part of the moon's disk, is plotted here for various lunar phases.

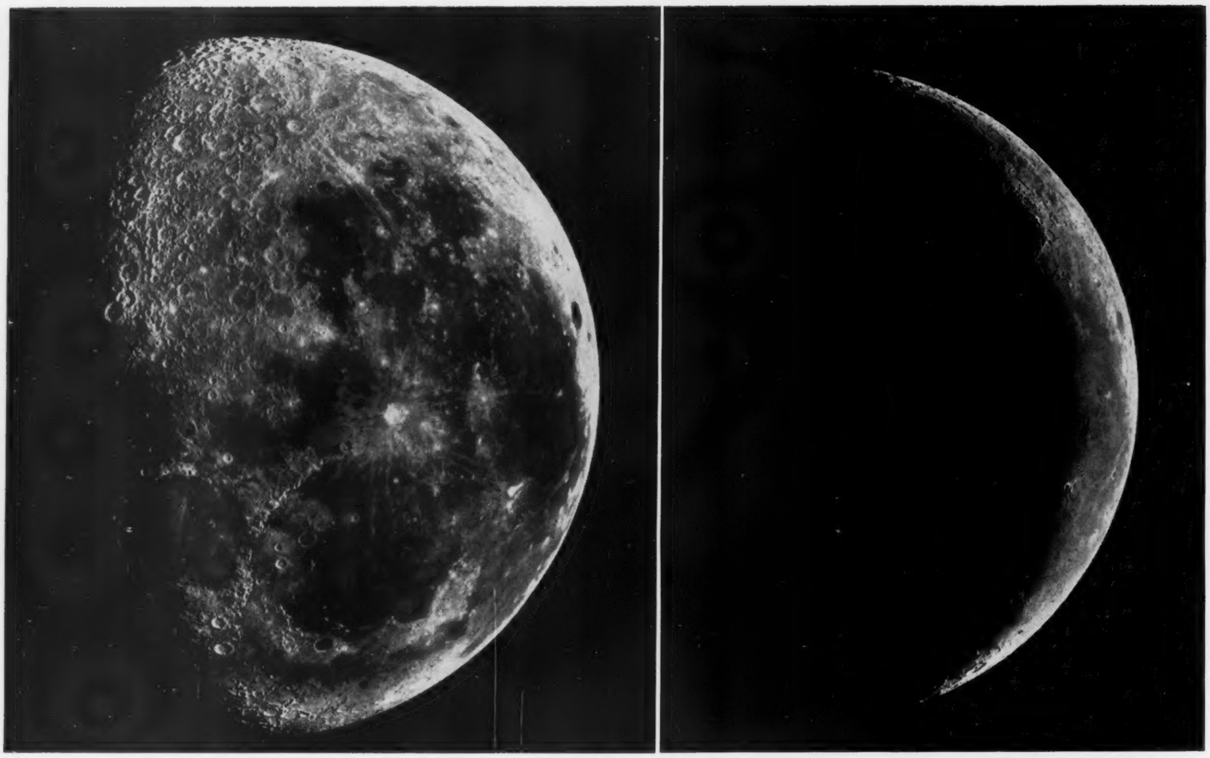
Once he had established in this way a uniform photometric system for all his pictures, van Diggelen could derive surface intensities of the 38 crater floors for five different phase angles: $+11\frac{1}{2}°$, $+24°$, $+78°$, $+91°$, and $+105°$. Despite the very large amount of labor spent, the work would have remained incomplete without adding the best available photometric measures made by other observers. Their data, recomputed so as to agree with van Diggelen's system of photometric units, were included in the final lunation curves, some being shown here.

The most noteworthy feature of the curves is that their maxima are close to phase angle 0° — at full moon irrespective of the crater's location on the lunar disk. However, there are several craters with maximum intensity occurring slightly after zero phase, for example at about +10° for Aristarchus and Tycho, and +5° for Proclus. Nearly all the craters exhibiting this anomaly have bright rays visible at full moon, and are generally regarded as being of relatively recent formation. But features like Alphonsus and Grimaldi, which because of their broken walls and floors are believed to be exceedingly old, habitually have maxima precisely at full moon.

The varied shapes of the lunation curves fit into a simple scheme. All crater floors located near the moon's central meridian have approximately symmetrical curves, as in the case of Archimedes. On the



These crater-floor lunation curves are based on all known reliable data. At the left, three craters near the moon's central meridian yield symmetrical curves, while that for Aristarchus close to the east limb is unsymmetrical.



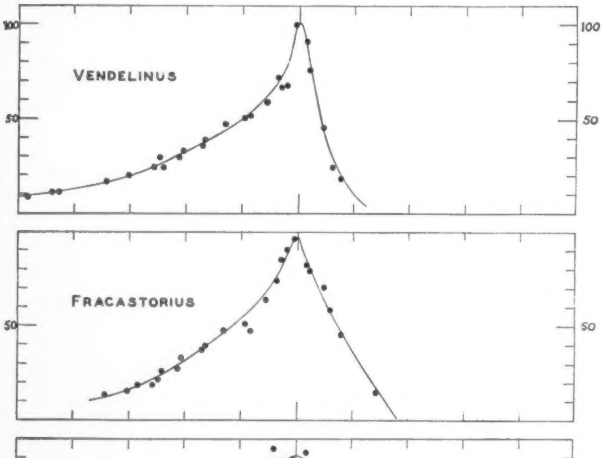
Compare the 20-day moon (left) with the 26-day-old waning crescent, the phase angles being about 60° and 130°, respectively. In the former, there is greater contrast between the "seas" and "continents," and dark craters like Grimaldi and bright ones like Aristarchus stand out more clearly. Lick Observatory photographs.

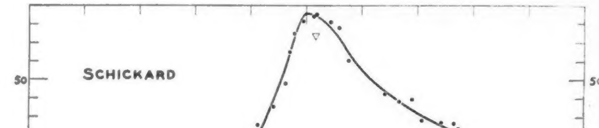
other hand, the curves are unsymmetrical for craters close to the east or west limb. Note the slow increase in surface brightness for Proclus, near the western limb, and the rapid drop to zero at phase angle about +45°. The opposite effect is shown by Schickard, which is well to the east of the central meridian. Its surface brightness remains zero until phase angle −30°, then rises sharply to a peak near full moon, thereafter decreasing slowly to zero again, at phase angle about +150°.

This asymmetry is readily explainable. The onset of brightness depends on the phase angle at which the sun's rays first illuminate the crater. As we have noted, all the curves have their peaks close to full moon. Hence it is obvious that before full moon the lunation curves must be steep for craters located near the eastern limb, and gradual for those near the western limb.

Another property of the curves is their great steepness near full moon. This is especially conspicuous for craters near the central meridian.

The heights of the curves are not all the same, for they depend to a large extent on the albedo (reflectivity) of each crater floor. There are several different definitions of albedo, but that by G. P. Bond is the one most often used in astronomy: the ratio of the total light re-





Above: Schickard and Proclus are examples of craters near the eastern and western limbs of the moon, respectively. They have oppositely distorted lunation curves.

Left: Three craters in the western part of the moon show the typical slowly rising curve and sharp drop.

flected from a sphere to the total light incident upon it.

Van Diggelen finds that the crater floors have Bond albedos ranging from 0.04 to 0.09, similar to laboratory values measured for dark terrestrial rocks and lavas. However, extensive recent work by the Soviet astronomers V. V. Sharonov and Mrs. N. N. Sytinskaya has not revealed any terrestrial rocks that exactly match the lunar surface in albedo and color. Van Diggelen has measured various volcanic ashes and obtained albedos of the right order of magnitude, confirming the widespread belief that much of the moon's surface is powdery.

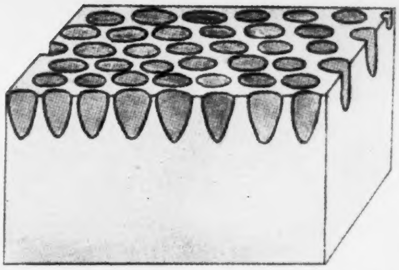
Generally, craters with bright rays have higher albedos than the others. Examples of this are Aristarchus, Tycho, and Proclus. The lunar maria (seas) have on the average slightly lower reflectivities than the craters, but the difference is not large.

Looking more closely into the shapes of the lunation curves, van Diggelen tested whether they were influenced by selenographic latitude. He intercompared several pairs of craters located at approximately the same distances north and south of the moon's equator, and found that the curves were almost exactly the same. This agreed with the 1949 finding by H. F. A. Tschunko that lunation-curve shapes (apart from differences in albedo) were the same for all latitudes, and depended only on the selenographical longitude.

A large part of the van Diggelen investigation dealt with the theoretical interpretation of his results. What optical laws govern them, and what can we infer about the physical nature of the lunar surface? The simplest law of diffuse reflection is Lambert's, which states that the brightness of a smooth surface is proportional to the cosine of the angle of incidence of the light rays. This reflection law cannot explain the lunation curves, because it places the maximum at zero angle of incidence, not at zero phase angle as is observed. The same objection applies to the Lommel-Seeliger law, an expression which involves the angle of emergence as well as the angle of incidence.

More complicated phase functions, such as the empirical ones of E. Opik in 1924 and V. G. Fessenkov in 1928, do not fit the observations. Furthermore, it is not possible to obtain a satisfactory agreement by using the scattering functions derived by S. Chandrasekhar for planetary atmospheres.

Hence, it is advisable to resort to an



Van Diggelen believes that a surface of this sort, honeycombed with semielliptical cups, has reflection properties similar to the moon's. All diagrams with this article are adapted from Vol. 14 of Utrecht Observatory's "Recherches Astronomiques."

interpretation given many years ago by the Princeton astronomers H. N. Russell, R. S. Dugan, and J. Q. Stewart. They state on page 173 of their *Astronomy*: "The half moon, though apparently of half the area of the full moon, is only one ninth as bright. Part of this difference arises from the fact that in the region near the terminator of the half moon the sun's rays strike the surface very obliquely, and therefore illuminate it feebly; but most of it must be due to the rough character of the lunar surface, which causes it to be more or less darkened, except at the full, by the shadows cast by its own irregularities. The shadows of the mountains which are visible with the telescope are probably of less importance than those of innumerable small irregularities, perhaps no bigger than boulders or even pebbles. A homely illustration of the same principle is that a broken road of rough but white snow appears darker than the surrounding smooth snow if one looks toward the sun, and brighter if one looks the other way."

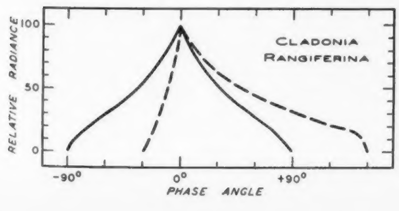
This approach to the problem was followed by A. L. Bennett, who in 1938 proposed that much of the moon's surface, perhaps half, is covered with little hemispherical pits, too small to be seen individually. But lunation curves computed on this assumption did not fit observed curves well in all cases, failing to be steep enough near their maxima. Bennett lessened this discrepancy by postulating deeper pits, half-ellipsoids instead of hemispheres. By further assuming the pits to be separated by ash-covered level spaces, van Diggelen was able to obtain an even better representation of the observations.

Because of the difficulty in fitting theoretical formulas to his photometric curves, van Diggelen carried out a series of laboratory experiments, in which he sought to simulate the lunation curves with terrestrial materials. Among the samples tested were volcanic ash, which has an albedo like that of crater floors; small glass beads, analogous to tektites which may occur on the moon; and metal plates covered with small pits or elevations. But the best match was obtained with a spongy material having numerous fine clefts, the lichen known as *Cladonia rangiferina*.

The photometric measurements of this lichen show a pronounced maximum at phase angle 0°, and resemble the curves obtained from observations of the moon. Van Diggelen concluded from this that the moon's surface is not merely a layer of dust, as has sometimes been suggested, but has an irregular, spongy character, somewhat like that of *Cladonia rangiferina*, with many randomly placed small-scale depressions and elevations.

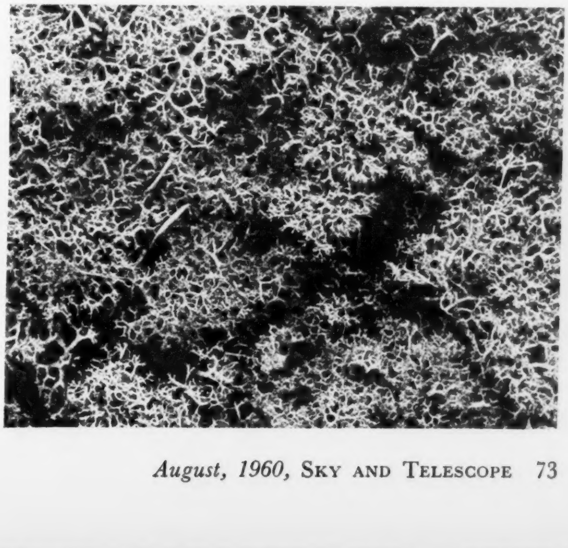
Apparently van Diggelen did not succeed in explaining why relatively young craters with bright rays show slightly displaced maxima of their lunation curves. Although most of such craters he observed are located in the moon's eastern hemisphere, there is at least one, Proclus, which is not far from the western limb. There seems no doubt that all these craters show maximum brightness after full moon. This is difficult to explain without assuming a very strange orientation of the spongy surface structure. The theoretical interpretation of this phenomenon is one of the next tasks for lunar experts.

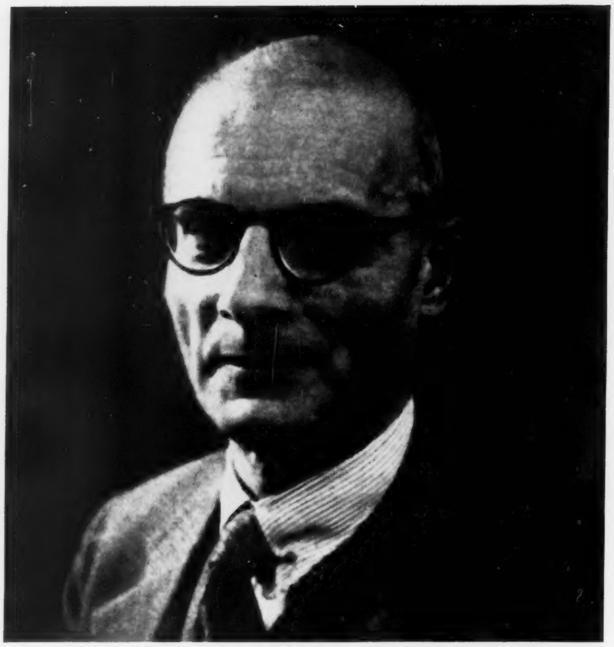
It would be interesting to know whether the lunation curves of the bright rays reach maximum shortly after full phase. Most observers merely state that the rays are brightest approximately at full moon.



Right: The structure of Cladonia rangiferina (reindeer moss).

Left: In the laboratory, van Diggelen obtained these "lunation curves" for Cladonia. The solid curve is for a moss sample whose apparent orientation was that of the center of the lunar disk, the dashed curve that of selenographic longitude 60°. Note the close resemblance to curves obtained for the moon itself.





Left: Antonie Pannekoek made important contributions to Milky Way studies, astrophysics, and the history of astronomy. Photograph by D. H. Menzel. Right: Pieter van Rhijn was an outstanding leader in stellar statistics.

Two Famous Dutch Astronomers

BART J. BOK, *Mount Stromlo Observatory, Australia*

WITHIN a fortnight, the Netherlands lost through death two of its truly great astronomers, Antonie Pannekoek on April 28th and Pieter van Rhijn on May 9th. The writer was the latter's pupil, proud in later life to be counted among his close personal and scientific friends. In my younger days, I benefited much by Pannekoek's advice and assistance and later also cherished his friendship. It is a privilege to write about these two men.

Antonie Pannekoek, the older of the two, was born in Vaassen in 1873. He studied at Leiden University, his doctoral dissertation in 1902 being about the eclipsing system of Algol. From 1899 to 1906, he was on the staff at Leiden Observatory, and from 1906 to 1914 was active politically in the socialist movement in Germany.

Pannekoek returned to Holland, to astronomical work and teaching in 1915. He founded the Astronomical Institute at the University of Amsterdam in 1921, where he was a professor until 1942, when dismissed by the German occupation forces. He and his wife shared many happy years of retirement in the Netherlands after the war. Until his death he remained an active worker, especially in the historical and philosophical aspects of astronomy.

Pieter van Rhijn was born at Gouda in 1886, but soon afterward his father was appointed a professor of theology at Groningen, where van Rhijn was educated. He became a pupil of J. C. Kapteyn, with whom he studied for his doctorate and to whose professorship he succeeded in 1921. Shortly before World War I, van Rhijn had visited America for a year, working at Mount Wilson Observatory, but for the remainder of his life always stayed close to Groningen. There he directed methodically, with care and imagination, the affairs and researches of the famous Kapteyn Astronomical Laboratory.

Toward the end of the second world war, he was stricken with tuberculosis, but recovered, remaining at his post until his retirement in 1956. Always active, at the time of his death he was putting the finishing touches on an article about stellar distribution for an astronomical compendium.

Both men have left their mark on the development of astronomy. Pannekoek was the independent thinker and innovator, whereas van Rhijn was principally thought of by astronomers as the highly competent co-ordinator of the world-wide co-operative "Plan of Selected Areas," which originated with Kapteyn. The standard distribution function for absolute brightnesses of the stars, which figures so prominently in modern evolutionary research, is always referred to in the literature as the "van Rhijn luminosity function."

During the first 40 years of his life, with Pannekoek's political activities seeming to overshadow his scientific work, there was no clearly defined line to his research efforts. But at the early age of 18, he had discovered the variability of Polaris from visual estimates. The present professor of astronomy at Amsterdam, G. B. van Albada, has found Pannekoek's detailed account of the Polaris observations, written in 1891 but unpublished. He had obtained an approximately correct period. Dr. van Albada writes to me further:

"He then continued his observations until 1899, when his duties at the observatory left him no more time for this (and other) nonprofessional astronomy. Since the amplitude of the variation was only 0.06 magnitude, his observations were not sufficiently consistent to give more than strong evidence. He published his results in 1913, after the studies by W. W. Campbell (1906, variable radial velocity), by E. Hertzsprung (1910, photographic), and by J. Stebbins (1912, photoelectric). This story indicates Pannekoek's ability as an observer and his self-restraint at a very early age."

Toward the beginning of his associa-

tion with Amsterdam, Pannekoek's plans for an over-all investigation of our Milky Way system developed. More than any other astronomer, he stressed the importance of accurate spectrographic classification for the study of the nearer parts of the Milky Way system, and his paper on the distribution of *A* and *B* stars, in Amsterdam *Publications*, Vol. 2, had a profound effect on our thinking about galactic structure. He developed, for the first time, the approach used so successfully in recent years by V. A. Ambarzumian and by W. W. Morgan in studying the spiral structure and grouping of stars in the galaxy.

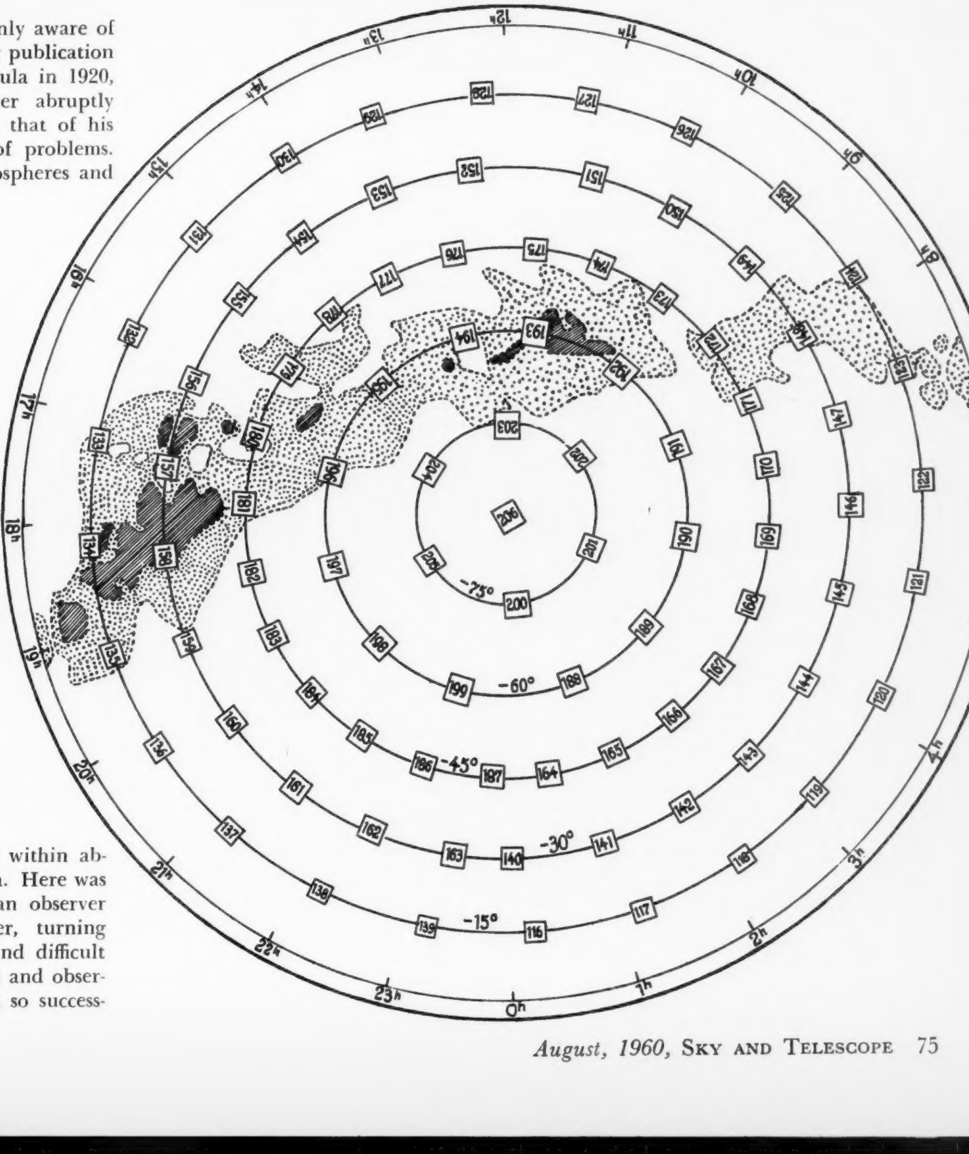
Pannekoek was above all a man in love with the beauty of the heavens. He began his observations of the Milky Way at the age of 16. On his travels, especially in the tropics (to Sumatra for the eclipse of January 14, 1926), he took every opportunity to draw, photograph, and measure the Milky Way's brightness distribution. Astronomers continue to consult his papers on the subject with pleasure and profit. His last published scientific report, in 1957, dealt with visual observation of color differences along the band of our galaxy, and their probable significance.

Pannekoek was always keenly aware of new trends in research. After publication of M. Saha's ionization formula in 1920, the Dutch astronomer rather abruptly shifted his own interest and that of his coworkers to a new group of problems. These concerned stellar atmospheres and the distribution of brightness within absorption lines in stellar spectra. Here was a man primarily trained as an observer and mathematical astronomer, turning in his late 40's to the new and difficult borderline fields of theoretical and observational astrophysics. He was so successful that his work in this area was a major contributing factor in the award to him of the gold medal of the Royal Astronomical Society (1951) and an honorary doctorate from Harvard University (1936).

Astrophysical problems continued to occupy Pannekoek mostly until the 1940's, when he had time to carry out historical studies. In 1951, he published a very fine volume on the history of astronomy, that has now been translated into English, and printed in London by Allen and Unwin. Some years ago, Mrs. Bok assisted Pannekoek with the correction of the English translation of his Dutch text. Both she and I, therefore, had an opportunity to sample its flavor. It is a remarkable book, in which the development of astronomy from Babylonian days onward is described and examined in relation to the social and political systems of the times. Throughout *A History of Astronomy,* the reader senses the deep concern with science and humanity that was so much a part of Pannekoek's versatile personality.

Van Rhijn was primarily a mathematical and statistical astronomer. He came to Groningen as a young student a few years after Kapteyn had announced the plan of selected areas, which dates back to 1904. Astronomers all over the world were to collect data on the brightnesses, colors, spectral characteristics, and motions of the stars, but this co-operative effort was to be limited primarily to 206 selected regions evenly distributed over the sky. It was Kapteyn's belief that through such a sampling we might arrive more quickly at a total picture of the structure of our Milky Way system than we would if the gathering of basic observational data were to proceed in a haphazard manner.

Van Rhijn became Kapteyn's assistant at the time the first of his large *durchmusterungs* was on the way, and it was largely under van Rhijn's direction that the three basic volumes published in Harvard *Annals* 101, 102, and 103, were completed. The necessary photographic plates for this undertaking were taken by Harvard and its Boyden station, and the standard magnitudes were determined by E. C. Pickering, Henrietta Leavitt, and others at Harvard. Similarly, van Rhijn became the coauthor with Kapteyn and F. H. Seares of the Mount Wilson



This sky chart, centered on the south celestial pole, shows the location of the southern selected areas, regions four degrees square that were chosen for intensive study. A similar pattern covers the northern sky. Much of van Rhijn's life was devoted to the determination of positions, magnitudes, and spectral types of stars in the 206 selected areas. On this chart the Milky Way is outlined according to Pannekoek's work. From a publication of Potsdam Observatory.

Catalogue of Photographic Magnitudes in Selected Areas 1-139.

After the death of Kapteyn, van Rhijn realized that knowledge of spectral types and magnitudes of the brighter stars in the selected areas would be of fundamental importance for future work. In the late 1920's (when I became van Rhijn's assistant), another large co-operative investigation got under way, involving Hamburg-Bergedorf Observatory, Harvard, and Kapteyn Astronomical Laboratory, with the first supplying spectral classifications, the second the basic photographic plates (with polar comparisons for standardization), and the third the measured magnitudes of all stars with known spectral types.

In addition, van Rhijn continued uninterruptedly statistical analyses based on the data gathered according to the selected-areas plan. He initiated and completed major studies relating to the stellar luminosity function. He also prepared extensive tables for the distribution of stars over the sky, thus building a firm foundation for all types of investigations relating to stellar distribution and obscuring matter in the nearer parts of our galaxy. Most of his findings are in a series known as the Groningen *Publications,* and it was only recently that the latest of these appeared on my desk here at Mount Stromlo.

From the start, the selected-areas program received world-wide support, and for many years now it has been the concern of an International Astronomical Union special commission, which was headed by van Rhijn. This commission continues to be active, and van Rhijn's lifework is not in danger of being abandoned. Although we place less reliance on being able to study the intricate design of our Milky Way system through soundings in portions of the sky evenly distributed over it, the selected areas have assumed increased importance as reference points for standards of all sorts. Away from the bright band of the Milky Way, the data gathered for the areas themselves are sufficiently representative to provide excellent basic information for the over-all features of galactic structure outside the central plane. In the years to come, the program of selected areas will most likely be enlarged and extended, especially for a study of faint, remote variable stars.

Astronomers have frequently honored van Rhijn and his work. In 1953, for example, 35 Milky Way specialists gathered near Groningen for a week-long symposium on the structure of our galaxy, the site being selected as a tribute to van Rhijn. In 1956 his pupils celebrated his 70th birthday by publishing a handsome little volume of essays.

It is an old saying that all Dutch astronomers are either pupils of Kapteyn, or pupils of pupils of Kapteyn, or — by now — of the third generation. Van Rhijn has long been among the best known of the first generation; Willem de Sitter was another.

Van Rhijn himself had many now distinguished students, among them the present director of Leiden, Jan H. Oort, and van Rhijn's successor at Groningen, Adriaan Blaauw. Jan Schilt, Columbia University, and Pieter van de Kamp, Swarthmore College, were pupils of van Rhijn, and others are at key astronomical posts in the Netherlands and in America. One of them has even gone to Australia!

Among Pannekoek's students were Dr. van Albada and his wife Elsa van Dien, and the well-known Dutch astronomers G. van Herk and T. Walraven. Although not a pupil of Pannekoek, the well-known astrophysicist H. Zanstra was his immediate successor at Amsterdam.

Antonie Pannekoek and Pieter van Rhijn both had long and happy lives. Each has earned a secure niche in the history of astronomy.

Three American Astronomers Die

THE United States lost three noted astronomers in June with the passing of Carl K. Seyfert, Frederick C. Leonard, and Walter Baade. On the night of June 13th, Dr. Seyfert, professor of astronomy at Vanderbilt University, was killed in an automobile collision in Nashville, Tennessee. Dr. Leonard, an authority on meteorites and professor of astronomy at the University of California, died in Los Angeles on June 23rd, at the age of 64. Two days later one of the outstanding astronomers of this century, Dr. Baade died at Göttingen in his native Germany, in his 68th year.

Born in Cleveland, Ohio, 49 years ago, Dr. Seyfert attended Harvard University and received his doctoral degree there in 1936. For four years he served as astronomer at McDonald Observatory in Texas, after which he was appointed National Research Council fellow at Mount Wilson Observatory.

From 1942 until he joined the Vanderbilt staff in 1946, he was associate professor of astronomy at Case Institute of Technology in Cleveland, where he obtained the first color photographs taken of stellar spectra. Throughout the war years, he did research on ballistics problems.

In 1951, Dr. Seyfert declined a Fulbright fellowship for study in the Netherlands, as he was then establishing the Arthur J. Dyer Observatory, with a 24-inch telescope equipped with a Baker reflector-corrector that can be used for wide-field photography as well as visual and photoelectric work. The observatory was dedicated in 1953, with Dr. Seyfert as director.

On the night of his death, he had just completed his evening weather forecast from a local television station. Dr. Seyfert and John H. DeWitt, Jr., of Station WSM-TV, had experimented with the application of television equipment to astronomical observations. Dr. Seyfert was a board member of the Association of Universities for Research in Astronomy, as well as Associated Universities, Inc. He was also a member of the International Astronomical Union's commission on extragalactic nebulae, a field in which he did research. Dr. Baade was president of this commission.

Dr. Leonard was born in Mt. Vernon, Indiana, receiving his doctorate in 1921 at the University of California, where he worked at Lick Observatory. In the next decade, he organized the department of astronomy at UCLA, becoming chairman in 1931.

During most of his life, Dr. Leonard was interested in meteorites, feeling that much concerning the nature of the universe could be learned from them. In 1942 he started to collect micrometeorites with a magnetic needle in Arizona, and found some weighing less than 1/300 ounce. Seven years later, he reported evidence indicating Wolf Creek crater in Western Australia to be of meteoritic origin.

Dr. Leonard became an expert in the classification of meteorites, setting up a system that attained wide acceptance. He was founder and past-president of the Meteoritical Society, originally called the Society for Research on Meteorites, and editor of its publications for 25 years. Among his many writings was the *Catalogue of the Meteoritic Falls of the World,* published in 1956. At the time of his death, Dr. Leonard was a member of the board of directors of the Astronomical Society of the Pacific.

After 27 years on the staff of Mount Wilson and Palomar Observatories, Walter Baade retired in 1958. Almost immediately he went to Göttingen University as visiting professor, but became ill soon afterward. While in California he made important discoveries as an observer with the 100- and 200-inch reflectors, and the 48-inch Schmidt telescope.

Two findings that have deeply influenced current astronomy are part of the legacy left by Dr. Baade, who was especially known for his studies of galaxies. One was his concept (1944) of two stellar populations; the other was his discovery that the galaxies were at least twice as distant as had been previously believed, an announcement he made at the 1952 Rome meeting of the IAU.

An account of Dr. Baade's career is planned for a future issue of SKY AND TELESCOPE.

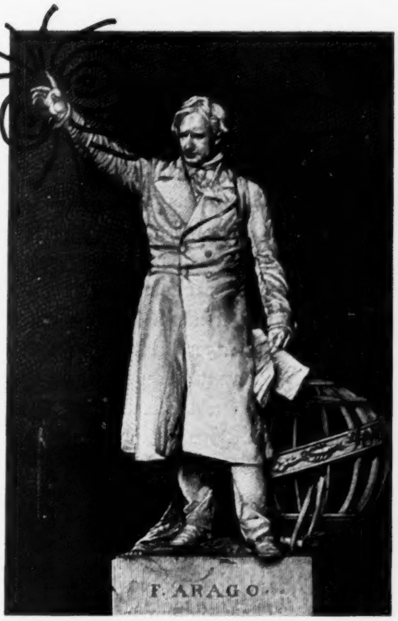
Magnetic Field Effects on Artificial Satellites

RAYMOND H. WILSON, JR., *Goddard Space Flight Center, National Aeronautics and Space Administration*

IN MODERN TIMES, the use of magnetic forces to influence mechanical rotation is so familiar as to go almost unnoticed. An electric motor, for instance, might more properly be called magnetic, since the electric current is merely the source of the energy for a sequence of interacting magnetic fields that actually drive the motor.

A less familiar example, in which magnetic forces retard rather than accelerate rotation, is the electromagnetic brake. A simple form of this, the Arago disk, was invented early in the 19th century by the director of the Paris Observatory, Francois Arago, who was a great popularizer of astronomy and physics. He noticed that any rotating metal disk, when partially immersed in a constant magnetic field having lines of force perpendicular to it, experienced a torque that tended either to bring the rotation to a halt, or to rotate the magnet with the disk.

To understand the action of this so-called eddy-current damping, consider a thin ring of material that is a conductor of electricity and is rotating relative to a surrounding magnetic field. The rotation is about an axis in the plane of the ring, so that the latter turns over and over. The rotation induces an electric current around the ring. In accordance with a generalization in physics known as Lenz's law, this induced current travels in such a direction that it produces a magnetic field having polarity opposite to the surrounding field, and the interaction of these two fields acts as a brake on the rotation of the ring.



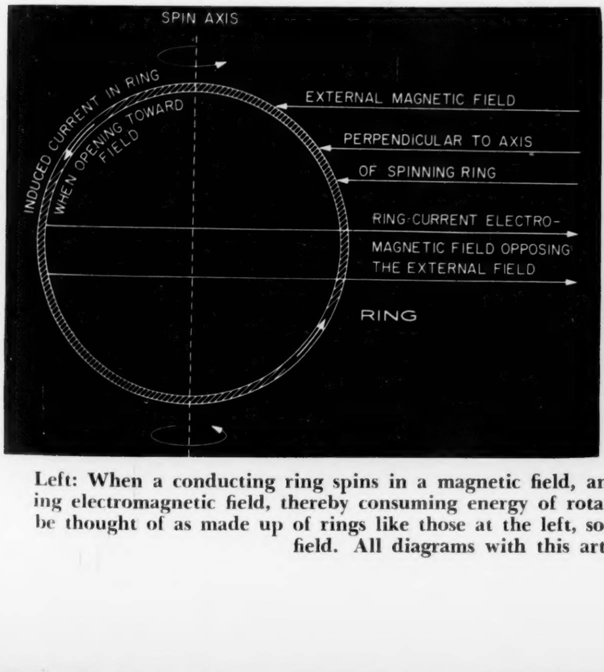
Dominique Francois Arago (1786-1853), a director of Paris Observatory, was better known as a physicist than as an astronomer. His discovery of the braking action of a magnetic field upon a rotating disk explains the diminishing spin of artificial satellites.

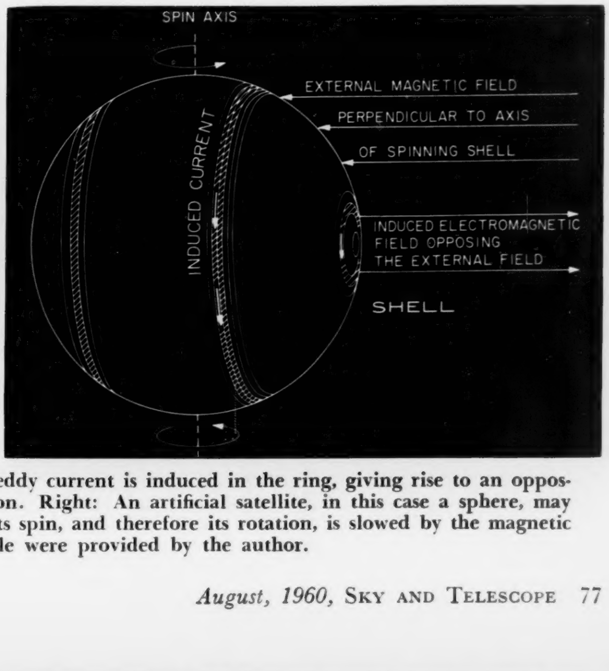
Since recent astronomical evidence indicates that outer space is permeated by magnetic fields, many rotating celestial masses having electrical conductivity will experience some such braking torque. Much attention has been given this problem in magnetohydrodynamics, where the mass consists mostly of an ionized gas or plasma, such as interstellar galactic material. But for space vehicles and, to some extent, planets and stars, we need consider only rigid bodies, and can obtain more definite numerical results.

For artificial satellites of the earth, the main spin-braking force is due to the geomagnetic field, with which the compass needle has made us familiar. The magnetic field at any point above the earth can be calculated. Furthermore, since many common metallic shapes used in satellites — spheres and cylinders, for example — may be considered mathematically as arrays of elemental rings, formulas can be set up for computing their rotational damping in the earth's field.

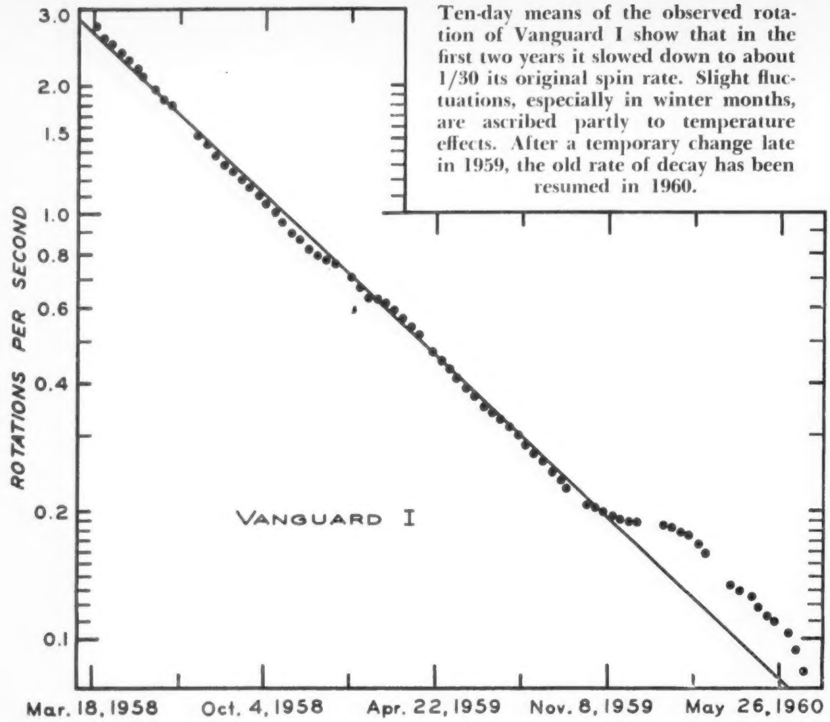
Beginning with Sputnik I, all artificial satellites have shown a decay in their rotation rate due to some braking action. However, many of the early satellites had perigee heights of only 200 miles or less, where the relatively dense air would produce a drag on protruding antennas or a nonspherical body. In these cases the magnetic action could not be clearly separated from the atmospheric effects.

The first two Vanguard satellites, 1958β2 and 1959α1, are spherically symmetrical and have perigees well above 300 miles. For spheres, it is optically difficult to





Left: When a conducting ring spins in a magnetic field, an eddy current is induced in the ring, giving rise to an opposing electromagnetic field, thereby consuming energy of rotation. Right: An artificial satellite, in this case a sphere, may be thought of as made up of rings like those at the left, so its spin, and therefore its rotation, is slowed by the magnetic field. All diagrams with this article were provided by the author.



Ten-day means of the observed rotation of Vanguard I show that in the first two years it slowed down to about 1/30 its original spin rate. Slight fluctuations, especially in winter months, are ascribed partly to temperature effects. After a temporary change late in 1959, the old rate of decay has been resumed in 1960.

observe the spin rate, although the turning of Vanguard I is presumably shown by the photograph on page 321 of the April, 1959, issue of SKY AND TELESCOPE. However, there have been frequent and fairly accurate radio measures of the Vanguard rotation from the antenna-attitude modulations of the satellite signal at Minitrack and other ground tracking stations.

Vanguard I, having solar-cell power, has transmitted radio signals from its launch date, March 17, 1958, to the present, permitting us to plot 10-day means of its observed spin rate, as shown here. Notice that the curve has, for two years, tended to follow a straight line on the logarithmic scale (an exponential decay). The spinning has slowed down by a factor of 2.718 every 230 days, and the rotation of 2.7 turns per second when the satellite went into orbit is less than 1/30 of that value now.

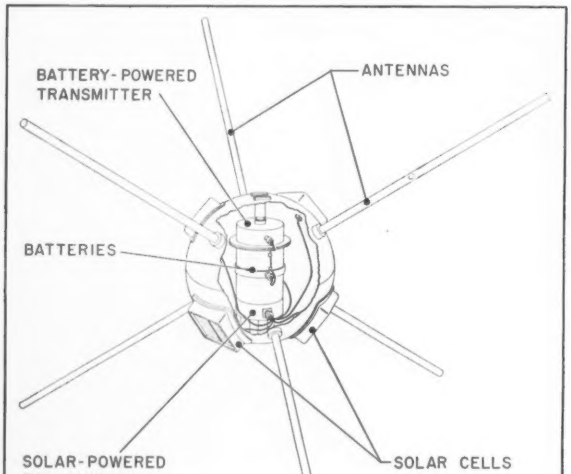
Some force that is proportional to the spin rate must be acting. We know, of course, what the moment of inertia of Vanguard I was when we constructed it, that is, we can calculate what its resistance to a change of rotation should be. The curve of the observed slowing down, combined with the moment of inertia, fixes the braking couple at a value of about 0.0035 unit (centimeter-gram-second system) when the rotation is one turn per second.

Next, with certain assumptions regarding the strength and direction of the earth's magnetic field as the satellite passes through it, we can compute the magnetic couple on various parts of the body: its aluminum spherical shell and ferromagnetic components. The dimensions of each element, its electrical conductivity and magnetic permeability, must be considered, as well as its position within the satellite with reference to the axis of rotation. Vanguard I data indicates within a few per cent that the slowing of the rotation is caused by the earth's magnetic field acting as a brake.

Magnetic permeability has a value of unity for a vacuum and nearly one for materials except the ferromagnetic metals: iron, cobalt, and nickel. Since the Vanguards contain mercury cells, each in a rolled-steel can with a permeability of about 40, the braking couple on these cans is about 1,600 times stronger than it would be had they been constructed of a metal like aluminum. This is because the magnetic torque is proportional to the square of the permeability. Thus, in Vanguard I the damping effect on the seven small cells alone is almost half as much as that on the remaining metallic portions, which weigh perhaps 10 times as much as the cells.

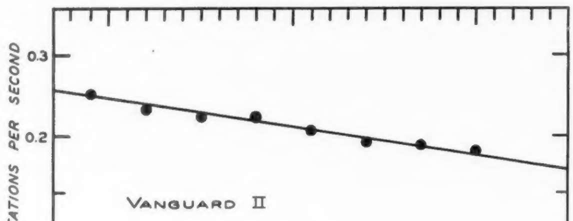
What about the fluctuations in the Vanguard I decay curve? The terrestrial magnetic field is known to vary with solar activity up to a few per cent. In addition, the magnetic permeability and electrical conductivity of most metals decrease with rising temperature, and the satellite interiors would have been hottest around December in both 1958 and 1959, just when the curve shows a lesser rate of rotation decay. At those times the Vanguard orbit was so oriented that the satellite was in sunlight 24 hours a day. Also, the earth was near perihelion and receiving the most energy from the sun, and the increased clouds and snow cover of the Northern Hemisphere reflected more heat to the satellite. The measured temperature of Vanguard I then actually exceeded 80° centigrade (50° above the mean for the satellite through the year), so the reduction of the conductivity and magnetic permeability should have been correspondingly greater.

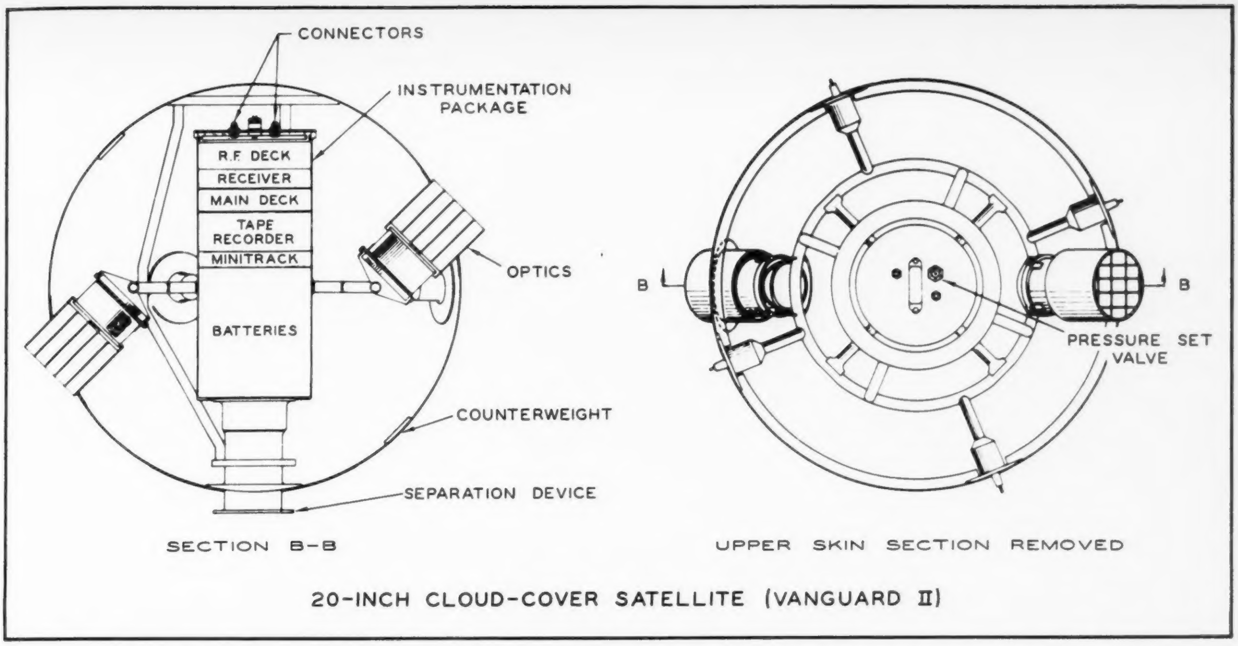
Vanguard II was launched February 17, 1959, but had no solar cells, so its spin rate could be observed by radio for only



Left: For Vanguard I, the main sources of magnetic damping were its outer shell of aluminum alloy, seven steel battery cans, three aluminum instrument packages, and six antennas.

Below: Vanguard II's rotation in 1959 was rapidly braked.





Most of the magnetic damping of Vanguard II's rotation is attributed to two small transformer cores.

a few weeks. The slowing down was more than three times as rapid as for its predecessor, amounting to the factor 2.718 in only 72 days. In 10 months, Vanguard II should thus be spinning at less than two per cent of its initial rate, the rotation period being lengthened to over three minutes. By October, 1960, it will have slowed to one rotation per revolution.

Thus, for this satellite a much larger braking torque, about 0.32 unit, is indicated for a one-second rotation time. From this can be deduced a mean total field close to the expected value of about 0.16 gauss, as inferred from ground surveys.

Vanguard II has a great number of ferromagnetic parts, but most of the total retardation is due to two small nickel-iron transformer cores having a magnetic permeability of over 2,000. The torque on them is over four million times that for a similar nonmagnetic mass. Surprisingly, much of the highly magnetic material experiences little or no damping couple. This is because it is either in permanent magnets or shields of these magnets, effectively saturated by fields thousands of times greater than the general geomagnetic field, which is negligible by comparison.

Magnetic damping drops to zero when the spin axis is parallel to the field lines shown by the compass and dipping needles. The space orientation of a satellite's spin axis could be observed directly if the outer surface consisted, at least partly, of flat facets. The model shown here, constructed at the Naval Research Laboratory, is a 30-inch sphere with 2,500 one-inch-square glass mirrors. These would reflect sunlight to an observer in intermittent flashes about seven times per rotation, on the average. However, since there are fewer mirrors on a small circle nearer to the satellite's pole of rotation, the satellite latitude of the reflected solar image could be estimated from the flash rate, and the orientation of the spin axis with reference to the sun would thus be known.

Another advantage of such a polyhedral reflecting surface is that the sun's image would be about as large as each flat face, instead of very tiny – only a millimeter in diameter seen in a smooth 20-inch sphere. Reflected in a one-inch flat mirror, the solar image at a 300-mile distance would appear as bright as the star Vega; even at the moon's distance the stellar magnitude would be +14, detectable in a 15-inch telescope.

The action of magnetic fields on the rotation of natural celestial bodies is usually too small and too involved with uncertain assumptions for clear demonstration. But our experience with magnetic damping in satellites can, perhaps, be applied to some astronomical problems. Among these is the dissipation of angular momentum during the evolution of the solar system, if that took place in a magnetic field. Thus, the sun's rotation might once have been only a few hours, compared to its present 25 days. For the moon and planets, it is important that space probes be used to determine their respective magnetic fields, as this information may be important in theoretical studies of the evolution of these bodies.

Our knowledge of changes in an artificial satellite's rotation can be considerably enhanced if frequent optical observations of the spin rate are obtained, and if data on the orientation of the spin axis were available. A satellite with a specially designed surface, like this one consisting of 2,500 small glass mirrors, may eventually allow us to obtain this information.

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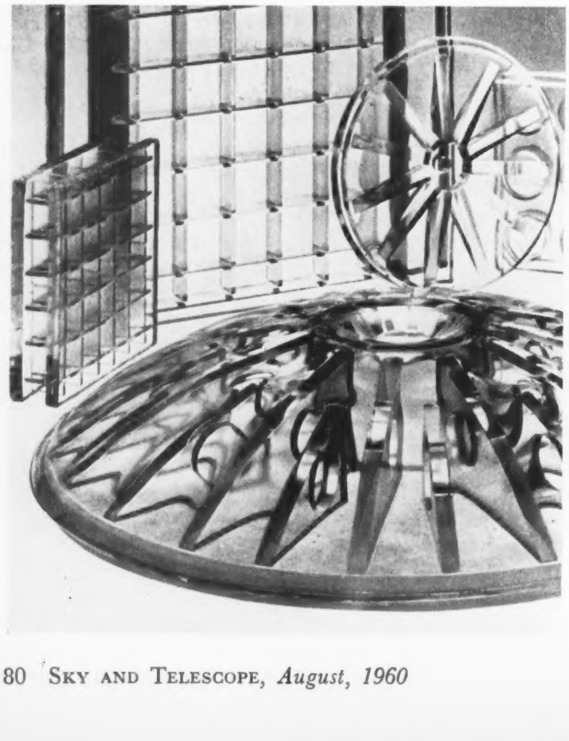

Some examples of the new lightweight mirror blanks being made by Corning Glass Works for use in missiles, satellites, and aircraft. The fused silica that forms the ribbed supports is the same as that of the mirror blank itself and changes very little with temperature fluctuations. Because there is such freedom of choice in size and shape, these blanks can be formed to meet the design requirements of virtually all reflecting telescope systems. Corning Glass Works photograph.

IN THE CURRENT JOURNALS

THE BUILDINGS AND OLD INSTRUMENTS OF THE ROYAL OBSERVATORY, GREENWICH, by P. S. Laurie, *Observatory*, February, 1960. "The original building consisted of little more than the dwelling-apartments and, above them, what is now known as the Octagon Room, a term apparently first used by G. B. Airy (1801-92) in 1835; the older name was always the Great Room. This room, 34 feet across and 18 feet high, is now restored to practically the same condition as when Flamsteed worked there."

GREAT AMERICAN SCIENTISTS: THE ASTRONOMERS, by George A. W. Boehm, *Fortune*, May, 1960. "The modern revolution in astronomy was shaped between 1910 and 1920, when men began finding answers to the three sweeping questions that have preoccupied astronomers ever since: What is the architecture and what are the dimensions of the universe? What makes stars shine? How has the universe evolved?"

RADIO ASTRONOMY – A WINDOW ON THE UNIVERSE, by J. H. Oort, *American Scientist*, June, 1960. "There can be no doubt that noiselessness is as essential for the further development of radio astronomy as darkness is for optical astronomy. But, in most parts of the world such noiselessness cannot be obtained by going away from the main centers of noise; more and more this noise will go around the whole world. It may well be that the necessary silence can only be obtained by a general international agreement to keep certain wave-length regions free from man-made signals."

OCCULTATIONS OF BRIGHT STARS BY PLANETS

The passage of Venus in front of the 1st-magnitude star Regulus on July 7, 1959, was the first event of its kind ever observed by astronomers (SKY AND TELESCOPE, September, 1959, page 606). The rarity of this phenomenon is made clear by the calculations of Jean Meeus, Kessel-Loo, Belgium, reported in the April *Journal* of the British Astronomical Association.

He has examined all the conjunctions of Venus with Regulus between A.D. 600 and A.D. 2600, and found that the planet occults the star only four times in this 20-century interval: on September 11, 1128; July 7, 1959; October 1, 2044; and October 6, 2271. It is uncertain in the last case whether a grazing occultation or a near miss will occur. The average fre-

quency of occultations of Regulus by Venus is once in 530 years.

Mr. Meeus has also investigated the possibilities of other planetary occultations of 1st-magnitude stars. Only five such stars are near enough to the ecliptic to be considered: Aldebaran, Pollux, Regulus, Spica, and Antares. At present, no planet can occult the first two of these. Mercury can occult Regulus and Spica, the former once every six centuries on the average. Antares and Spica can be occulted by Venus, but only once in about 2,000 years in the case of Spica.

Except for a possible Neptune occultation of Regulus some centuries in the future, no superior planet can occult a 1st-magnitude star. But perturbations may eventually change the situation for some planets. For example, about A.D. 6000 Venus will be able to occult Aldebaran.

MAGNETIC FIELD OF THE GALAXY

In recent years, astrophysicists have often suggested that the Milky Way system has a general magnetic field. Such a field would help explain the polarization of starlight, certain properties of cosmic rays, and the stability of the galaxy's spiral arms. Theoretical estimates of the magnetic field intensity in the galaxy have ranged from 7×10^{-6} gauss (S. Chandrasekhar and E. Fermi) up to 10^{-4} (L. Davis, Jr., and J. Greenstein).

At the Jodrell Bank Experimental Station in England, J. A. Galt, C. H. Slater, and W. L. H. Shuter have used the 250-foot radio telescope in an attempt to detect the galactic field. They studied the absorption lines at 21 centimeters wave length produced in the radio spectrum of the strong source Cassiopeia A by clouds of interstellar neutral hydrogen. They selected the narrowest of the lines, which has a half-width of 18 kilocycles and is associated with the Orion spiral arm of our galaxy.

If this interstellar hydrogen lies in a magnetic field, the Zeeman effect takes place in one of two ways. When the line of sight is perpendicular to the lines of force, the 21-cm. absorption line will be split into three plane-polarized components, but too close together to be resolved directly. If, however, the line of sight is along the lines of force, the Zeeman effect produces two close components that are circularly polarized in opposite directions. Their small displacements may be detected with a system sensitive to changes in the sense of the circular polarization.

For the observations, the large radio telescope was fitted with a narrow-band receiver, which could switch rapidly between the right-handed and left-handed polarizations. Careful scans of the 21-cm. line failed to show any significant Zeeman effect, leading the three radio astronomers to suggest that the magnetic field in the Orion arm's interstellar hydrogen cloud is less than about 5×10^{-5} gauss.

However, the line of sight to Cassiopeia A is inclined about 45 degrees to the Orion arm, and if the magnetic field is aligned with the spiral arm, the corresponding upper limit for the arm must be raised by about 1.4 times.

Details of this work were presented in the March *Monthly Notices* of the Royal Astronomical Society.

MOLECULAR ASTRONOMY

In an article well suited to study by amateur astronomers, the late Andrew McKellar, Dominion Astrophysical Observatory, discusses some topics in molecular astronomy. It is published in the June issue of the *Journal* of the Royal Astronomical Society of Canada, with a number of spectra.

The subjects include spectroscopy of the atmosphere of Venus, bands of CN in cometary spectra and of ionized nitrogen molecules in sunlit auroras, interstellar lines (with a table of 10 diffuse interstellar absorption features that are unidentified), and the cool carbon stars. The Canadian astronomer was especially well known for his studies of the abundance ratio of carbon isotopes 12 and 13, a problem of importance in the origin of the elements and the generation of stellar energy.

LITHIUM ABUNDANCES IN T TAURI STARS

In the earth and in the sun's atmosphere, the proportions of the heavy metallic elements, such as calcium, iron, and nickel, are relatively about the same. But among the lighter elements there are notable differences: Hydrogen and helium are far more abundant on the sun, while the earth has relatively much more lithium. Presumably, in the sun and cooler stars this last element has been destroyed by some process.

Recently W. K. Bonsack and Jesse L. Greenstein, California Institute of Technology, have measured the doublet line of neutral lithium, at a wave length of 6708 angstroms, in the spectra of 12 stars. Four of these are T Tauri-type stars involved in nebulosity, while the eight others are similar to the former in some respects. The doublet is a very strong feature of T Tauri itself, RY Tauri, RW Aurigae, GW Orionis and also SU Aurigae, which has a red spectrum very much like that of T Tauri.

For all five objects, the lithium-to-metals ratio exceeds the solar value by a factor of 100 and is approximately equal to the terrestrial ratio. This result suggests that these five are young stars that have one lithium atom for every billion hydrogen atoms; it is in accordance with the theory that T Tauri objects were recently formed and are still in the contracting stage of their evolution. The remaining stars examined had no detectable lithium.

An estimate of the lithium abundance in the nebula surrounding T Tauri was made, since presumably this material formed part of the cloud from which the star condensed. Apparently, there is at least 10 times more lithium per gram in T Tauri's atmosphere than in the surrounding nebula — a striking reversal of the situation in the solar system. In the January *Astrophysical Journal*, the California astronomers speculate on various mechanisms that might produce such an abundance anomaly.

QUESTIONS... FROM THE S+T MAILBAG

Q. How can I minimize the fogging of star photographs taken during moonlight?

A. Stopping down the lens and short exposures are a help. Use a red-sensitive film and red filter, since scattered moonlight is relatively blue. Even with these techniques, good photographs are generally not possible within two days or so of full moon, or on bright moonlit nights when sky transparency is poor.

Q. Has any refracting telescope larger than the Yerkes 40-inch been made?

A. Yes, a refractor of 49.2-inch aperture was built at Paris in 1900. It did not fulfill expectations, and was soon dismantled. Its story was told in the August, 1958, issue of SKY AND TELESCOPE, page 509.

Q. When is the next opposition of Mars?

A. On December 30th of this year, when the planet's disk will have an apparent diameter of 15.4 seconds of arc. Nearest approach to the earth (56.4 million miles) occurs five days earlier.

Q. Why are tank prisms not recommended as diagonals for reflecting telescopes?

A. Their surfaces are usually not sufficiently flat for such a critical use. Furthermore, if the prism has been cut from a larger one, the relieved stresses in the glass will warp it.

Q. Which are the three nearest globular star clusters?

A. According to the data in the Skalnate Pleso *Atlas Catalogue*, the nearest is NGC 6553 in Sagittarius, 4,200 light-years distant; next are NGC 6539 in Serpens, 5,200 light-years, and NGC 6760 in Aquila, 6,800. All three are relatively small, faint clusters.

Q. When is the next sunspot maximum expected?

A. In 1968, according to C. M. Minnis of the Radio Research Station, Slough, England. However, he predicts that sunspots will not be as numerous then as in 1958, when the latest sunspot maximum occurred.

W. E. S.

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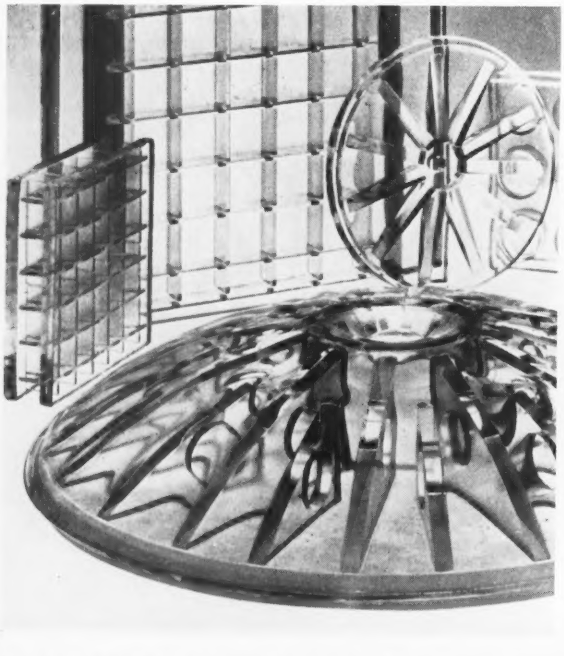


Some examples of the new lightweight mirror blanks being made by Corning Glass Works for use in missiles, satellites, and aircraft. The fused silica that forms the ribbed supports is the same as that of the mirror blank itself and changes very little with temperature fluctuations. Because there is such freedom of choice in size and shape, these blanks can be formed to meet the design requirements of virtually all reflecting telescope systems. Corning Glass Works photograph.

IN THE CURRENT JOURNALS

THE BUILDINGS AND OLD INSTRUMENTS OF THE ROYAL OBSERVATORY, GREENWICH, by P. S. Laurie, *Observatory*, February, 1960. "The original building consisted of little more than the dwelling-apartments and, above them, what is now known as the Octagon Room, a term apparently first used by G. B. Airy (1801-92) in 1835; the older name was always the Great Room. This room, 34 feet across and 18 feet high, is now restored to practically the same condition as when Flamsteed worked there."

GREAT AMERICAN SCIENTISTS: THE ASTRONOMERS, by George A. W. Boehm, *Fortune*, May, 1960. "The modern revolution in astronomy was shaped between 1910 and 1920, when men began finding answers to the three sweeping questions that have preoccupied astronomers ever since: What is the architecture and what are the dimensions of the universe? What makes stars shine? How has the universe evolved?"

RADIO ASTRONOMY – A WINDOW ON THE UNIVERSE, by J. H. Oort, *American Scientist*, June, 1960. "There can be no doubt that noiselessness is as essential for the further development of radio astronomy as darkness is for optical astronomy. But, in most parts of the world such noiselessness cannot be obtained by going away from the main centers of noise; more and more this noise will go around the whole world. It may well be that the necessary silence can only be obtained by a general international agreement to keep certain wave-length regions free from man-made signals."

OCCULTATIONS OF BRIGHT STARS BY PLANETS

The passage of Venus in front of the 1st-magnitude star Regulus on July 7, 1959, was the first event of its kind ever observed by astronomers (SKY AND TELESCOPE, September, 1959, page 606). The rarity of this phenomenon is made clear by the calculations of Jean Meeus, Kessel-Loo, Belgium, reported in the April *Journal* of the British Astronomical Association.

He has examined all the conjunctions of Venus with Regulus between A.D. 600 and A.D. 2600, and found that the planet occults the star only four times in this 20-century interval: on September 11, 1128; July 7, 1959; October 1, 2044; and October 6, 2271. It is uncertain in the last case whether a grazing occultation or a near miss will occur. The average fre-

quency of occultations of Regulus by Venus is once in 530 years.

Mr. Meeus has also investigated the possibilities of other planetary occultations of 1st-magnitude stars. Only five such stars are near enough to the ecliptic to be considered: Aldebaran, Pollux, Regulus, Spica, and Antares. At present, no planet can occult the first two of these. Mercury can occult Regulus and Spica, the former once every six centuries on the average. Antares and Spica can be occulted by Venus, but only once in about 2,000 years in the case of Spica.

Except for a possible Neptune occultation of Regulus some centuries in the future, no superior planet can occult a 1st-magnitude star. But perturbations may eventually change the situation for some planets. For example, about A.D. 6000 Venus will be able to occult Aldebaran.

MAGNETIC FIELD OF THE GALAXY

In recent years, astrophysicists have often suggested that the Milky Way system has a general magnetic field. Such a field would help explain the polarization of starlight, certain properties of cosmic rays, and the stability of the galaxy's spiral arms. Theoretical estimates of the magnetic field intensity in the galaxy have ranged from 7×10^{-6} gauss (S. Chandrasekhar and E. Fermi) up to 10^{-4} (L. Davis, Jr., and J. Greenstein).

At the Jodrell Bank Experimental Station in England, J. A. Galt, C. H. Slater, and W. L. H. Shuter have used the 250-foot radio telescope in an attempt to detect the galactic field. They studied the absorption lines at 21 centimeters wave length produced in the radio spectrum of the strong source Cassiopeia A by clouds of interstellar neutral hydrogen. They selected the narrowest of the lines, which has a half-width of 18 kilocycles and is associated with the Orion spiral arm of our galaxy.

If this interstellar hydrogen lies in a magnetic field, the Zeeman effect takes place in one of two ways. When the line of sight is perpendicular to the lines of force, the 21-cm. absorption line will be split into three plane-polarized components, but too close together to be resolved directly. If, however, the line of sight is along the lines of force, the Zeeman effect produces two close components that are circularly polarized in opposite directions. Their small displacements may be detected with a system sensitive to changes in the sense of the circular polarization.

For the observations, the large radio telescope was fitted with a narrow-band receiver, which could switch rapidly between the right-handed and left-handed polarizations. Careful scans of the 21-cm. line failed to show any significant Zeeman effect, leading the three radio astronomers to suggest that the magnetic field in the Orion arm's interstellar hydrogen cloud is less than about 5×10^{-5} gauss.

However, the line of sight to Cassiopeia A is inclined about 45 degrees to the Orion arm, and if the magnetic field is aligned with the spiral arm, the corresponding upper limit for the arm must be raised by about 1.4 times.

Details of this work were presented in the March *Monthly Notices* of the Royal Astronomical Society.

MOLECULAR ASTRONOMY

In an article well suited to study by amateur astronomers, the late Andrew McKellar, Dominion Astrophysical Observatory, discusses some topics in molecular astronomy. It is published in the June issue of the *Journal* of the Royal Astronomical Society of Canada, with a number of spectra.

The subjects include spectroscopy of the atmosphere of Venus, bands of CN in cometary spectra and of ionized nitrogen molecules in sunlit auroras, interstellar lines (with a table of 10 diffuse interstellar absorption features that are unidentified), and the cool carbon stars. The Canadian astronomer was especially well known for his studies of the abundance ratio of carbon isotopes 12 and 13, a problem of importance in the origin of the elements and the generation of stellar energy.

LITHIUM ABUNDANCES IN T TAURI STARS

In the earth and in the sun's atmosphere, the proportions of the heavy metallic elements, such as calcium, iron, and nickel, are relatively about the same. But among the lighter elements there are notable differences: Hydrogen and helium are far more abundant on the sun, while the earth has relatively much more lithium. Presumably, in the sun and cooler stars this last element has been destroyed by some process.

Recently W. K. Bonsack and Jesse L. Greenstein, California Institute of Technology, have measured the doublet line of neutral lithium, at a wave length of 6708 angstroms, in the spectra of 12 stars. Four of these are T Tauri-type stars involved in nebulosity, while the eight others are similar to the former in some respects. The doublet is a very strong feature of T Tauri itself, RY Tauri, RW Aurigae, GW Orionis and also SU Aurigae, which has a red spectrum very much like that of T Tauri.

For all five objects, the lithium-to-metals ratio exceeds the solar value by a factor of 100 and is approximately equal to the terrestrial ratio. This result suggests that these five are young stars that have one lithium atom for every billion hydrogen atoms; it is in accordance with the theory that T Tauri objects were recently formed and are still in the contracting stage of their evolution. The remaining stars examined had no detectable lithium.

An estimate of the lithium abundance in the nebula surrounding T Tauri was made, since presumably this material formed part of the cloud from which the star condensed. Apparently, there is at least 10 times more lithium per gram in T Tauri's atmosphere than in the surrounding nebula — a striking reversal of the situation in the solar system. In the January *Astrophysical Journal,* the California astronomers speculate on various mechanisms that might produce such an abundance anomaly.

QUESTIONS... FROM THE S+T MAILBAG

Q. How can I minimize the fogging of star photographs taken during moonlight?

A. Stopping down the lens and short exposures are a help. Use a red-sensitive film and red filter, since scattered moonlight is relatively blue. Even with these techniques, good photographs are generally not possible within two days or so of full moon, or on bright moonlit nights when sky transparency is poor.

Q. Has any refracting telescope larger than the Yerkes 40-inch been made?

A. Yes, a refractor of 49.2-inch aperture was built at Paris in 1900. It did not fulfill expectations, and was soon dismantled. Its story was told in the August, 1958, issue of SKY AND TELESCOPE, page 509.

Q. When is the next opposition of Mars?

A. On December 30th of this year, when the planet's disk will have an apparent diameter of 15.4 seconds of arc. Nearest approach to the earth (56.4 million miles) occurs five days earlier.

Q. Why are tank prisms not recommended as diagonals for reflecting telescopes?

A. Their surfaces are usually not sufficiently flat for such a critical use. Furthermore, if the prism has been cut from a larger one, the relieved stresses in the glass will warp it.

Q. Which are the three nearest globular star clusters?

A. According to the data in the Skalnate Pleso *Atlas Catalogue,* the nearest is NGC 6553 in Sagittarius, 4,200 light-years distant; next are NGC 6539 in Serpens, 5,200 light-years, and NGC 6760 in Aquila, 6,800. All three are relatively small, faint clusters.

Q. When is the next sunspot maximum expected?

A. In 1968, according to C. M. Minnis of the Radio Research Station, Slough, England. However, he predicts that sunspots will not be as numerous then as in 1958, when the latest sunspot maximum occurred. W. E. S.

This large spiral galaxy is Messier 81, about eight million light-years distant, in the constellation Ursa Major. In its spiral arms the 120-inch telescope reveals starclouds, groups of the brightest individual stars, luminous gas clouds, and dark dust lanes. Most of the light comes from the myriads of unresolved fainter stars strongly concentrated toward the central regions. The fine, long curved arms suggest rotation, which has been confirmed by spectrographic observations. This 30-minute exposure on a blue-sensitive emulsion was taken by George H. Herbig on January 31, 1960.

Compare these photographs of the 12th-magnitude spiral NGC 2146. A one-hour exposure with the 36-inch Crossley reflector was used for the picture on the left. The other was obtained in 20 minutes on 103a-O emulsion behind a GG-13 filter with the new 120-inch, on December 1, 1959, and is enlarged 4.2 times. There is far greater detail in this picture. The curious multibranched dark marking is due to absorbing lanes of dust. Because it is located only 12 degrees from the north celestial pole, NGC 2146 could not be reached by E. Hubble with Mount Wilson's 100-inch reflector.

Lick 120-inch Photographs — II

This dark nebula with a luminous rim is situated at the edge of the very open star cluster IC 1848 in Cassiopeia. One inch diagonally upward and to the right of the bright star in lower center is the nebulous image of a peculiar variable, LW Cassiopeiae, of magnitude 15 or 16. It was discovered in 1953 by N. E. Kurockin, Moscow Observatory, who regarded it as akin to the novae. George H. Herbig took this 30-minute red-light exposure with the 120-inch telescope on December 6, 1959. The enlargement is about 2½ times. All photographs are courtesy Lick Observatory.

OBSERVING THE SATELLITES

TWIN PAYLOADS

IN an unprecedented launching from Cape Canaveral, Florida, on June 22nd at 5:54:08 Universal time, two new instrumented satellites were put into nearly identical orbits by the same carrier. Both payloads were sponsored by the U. S. Navy, but have quite different purposes. The larger, Transit II-A, is one of a series for developing a new, precise, all-weather navigation system, while its smaller companion is intended to detect solar radiation.

As with the Transit I-B sent aloft on April 13th (SKY AND TELESCOPE, June, 1960, page 461), the first-stage booster was a modified Thor IRBM, and an Able-Star provided second-stage propulsion. The recent firing was programmed so that the carrier turned southeastward, instead of heading northeast over the Atlantic. The Able-Star coasted over South America from Colombia to Uruguay. Then, about 25 minutes after take-off, when the jet-stabilized rocket was approaching latitude 45° south, longitude 45° west, its engine was restarted to give additional speed.

Transit II-A thus became satellite 1960-η1, as designated by Space Track. Its companion, pushed off by spring pressure after explosive charges released a holding clamp, became 1960η2. Accompanying these two objects but much brighter than them is 1960η3, the burnt-out last-stage rocket, 14.8 feet long and 4.6 feet in diameter. Both payloads have periods of 101.66 minutes, with perigees of 397 and apogees of 658 miles. Corresponding figures for η3 are 101.37, 391, and 647. All objects have inclinations of 66°.77.

Superficially, Transit II-A is like its predecessor. Both are about 36 inches in diameter, with spiral antennas painted on their fiberglass surfaces. But the newer satellite carries about twice as many solar cells around its girdle, so that no primary chemical batteries were included. In this way the weight was kept down to only 223 pounds, making it possible to launch an additional 40-pound satellite at the same time, since the two together weigh almost as much as Transit I-B.

Apparently, it was desirable to divide the instruments into two separate packages because of different spin requirements. For the first week, both satellites were to rotate at approximately equal rates. Later, to avoid unwanted modulation of its radio signals, the spin of Transit II-A will be much reduced. This is to be accomplished by the release of two weights attached to long cables that will be unwound by centrifugal force. Afterward, the rotation will be further reduced progressively, as the earth's magnetic field interacts with eight highly permeable rods, wrapped with shorted coils of wire. (The principle of this mechanism is explained by Raymond H. Wilson, Jr., in his article on page 77 of this issue.) Similar devices slowed the rotation rate of Transit I-B.

As the weights slip away from Transit II-A, they will carry with them antennas for monitoring 3.8-megacycle cosmic radio noise. This experiment, designed by Canada's Defense Research Telecommunications Establishment at Ottawa, is the first case of international co-operation in the development of an orbiting payload. The Canadian receiver is the prototype of a similar instrument for sounding the ionosphere from above.

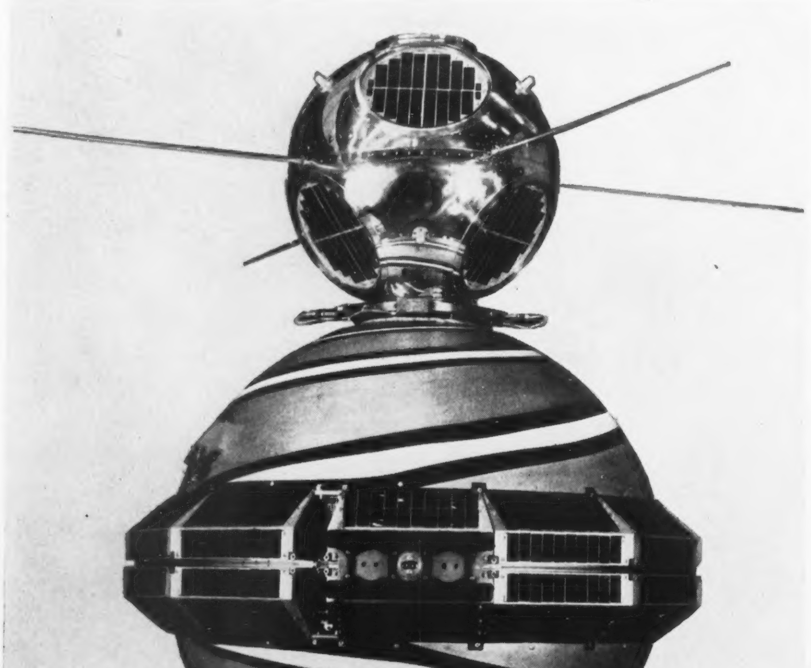
Already, the earlier Transit had tested many design features needed for successful operation of the new navigational system, which depends on measuring from shipboard the Doppler shift of radio signals transmitted from an orbiting satellite. A vital requirement is frequency stability, for any changes during the 15 minutes when a ship monitors the satellite would result in an erroneous geographical position. With Transit I-B, a short-term frequency stability of one part in 10^9 was achieved by keeping the temperature of the frequency-controlling crystals constant to within 0.00001° Fahrenheit per day.

The same arrangement for temperature control is used in the new Transit II-A. The crystals are kept in double-walled Dewar flasks hanging by nylon cords from the instrument tray, which is similarly laced to the satellite's $\frac{1}{4}$-inch shell, whose inside is painted with gold.

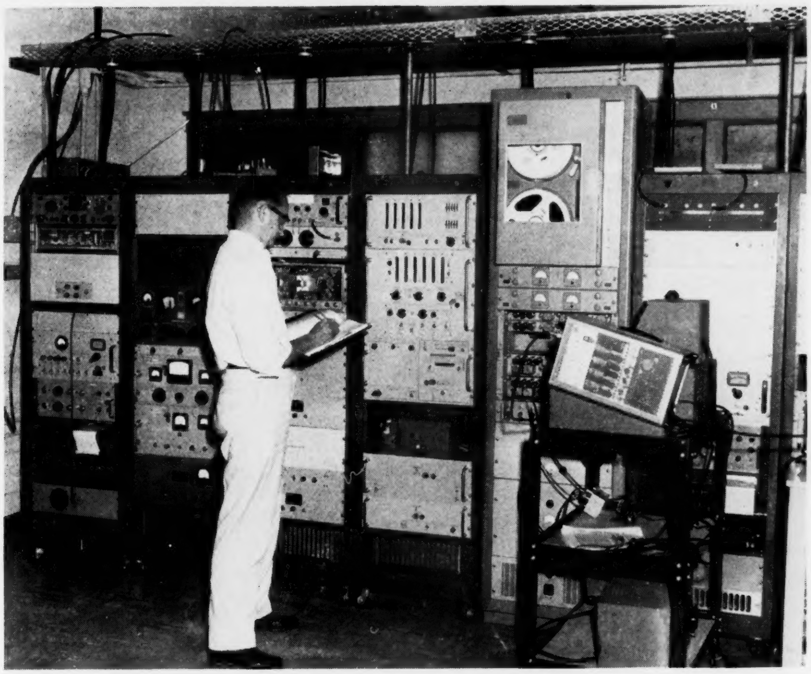
The equipment section of Transit II-A is thermally protected by alternate layers of fiberglass and aluminum foil, maintaining a temperature of +48° F. with a change of less than a degree per day, while the skin temperature varies from −10° to +150°.

One practical problem of the Transit system for navigation had given particular concern — the effect of ionospheric refraction upon the received frequency. But the operation of Transit I-B has shown that this can be adequately compensated by using two frequencies, since, to a sufficient approximation, the percentage error in the measured radial velocity of the satellite relative to the observer varies inversely as the square of the transmitter frequency. I-B carried two pairs of transmitters to check this, and similar equipment is aboard II-A.

In using the Transit system, the ship's navigator must know the time to within 0.01 second, since he is determining his geographical position relative to an arti-



The 20-inch spherical payload for measuring solar radiation was mounted piggyback on the navigational satellite Transit II-A, which carries a girdle of solar cells. Johns Hopkins University photograph.



Signals from the Transit satellite are being received at the Applied Physics Laboratory of Johns Hopkins University, which is the computing center for the seven receiving stations. Much simpler and less expensive equipment than this will be used on ships that employ the Transit system of radio navigation. Johns Hopkins University photograph.

ficial satellite traveling about four miles per second. Therefore, it is planned that operational satellites will transmit their own time signals (as well as frequently updated orbital data). Transit II-A is equipped with a frequency divider for signals from its crystal oscillator.

Evidently, the precision of navigational fixes obtained through an orbiting satellite depends on how well its position at any moment is known relative to a terrestrial co-ordinate system. Simple orbit theory does not suffice, for perturbations must be considered. The satellite's motion is perturbed by the asymmetries of the earth's gravitational field, of which two examples are the well-known bulge of the earth's equator and the slight "pear-shaped" distortion discovered from Vanguard I observations. The motion of Transit I-B has already yielded information about this kind of distortion. This investigation is being continued with Transit II-A.

Also included in the new Transit vehicle is an infrared scanner that will aid in developing the Midas system for early detection of rocket firings. In addition, since the scanner can distinguish between earth and sky, it serves to measure the rotation rate of the satellite. The data from this and other Transit II-A experiments are being telemetered to earth by 107.903- and 108.06-megacycle transmitters.

The solar-radiation satellite, 1960η2, is a 20-inch aluminum sphere, carrying six symmetrically arranged patches of solar cells. Nine inches in diameter, each patch has 156 cells, covered by fused-silica windows. Four 25-inch tubular antennas are arrayed around the equator of the sphere, designed by the Naval Research Laboratory.

The purpose of this payload is the long-term measurement of two types of solar radiation that have a profound influence on the earth's many-layered atmosphere. One sensor measures the intensity of the sun's Lyman-alpha light at 1216 angstrom units in the far ultraviolet. The other detector is sensitive to solar X-rays with wave lengths below eight angstroms.

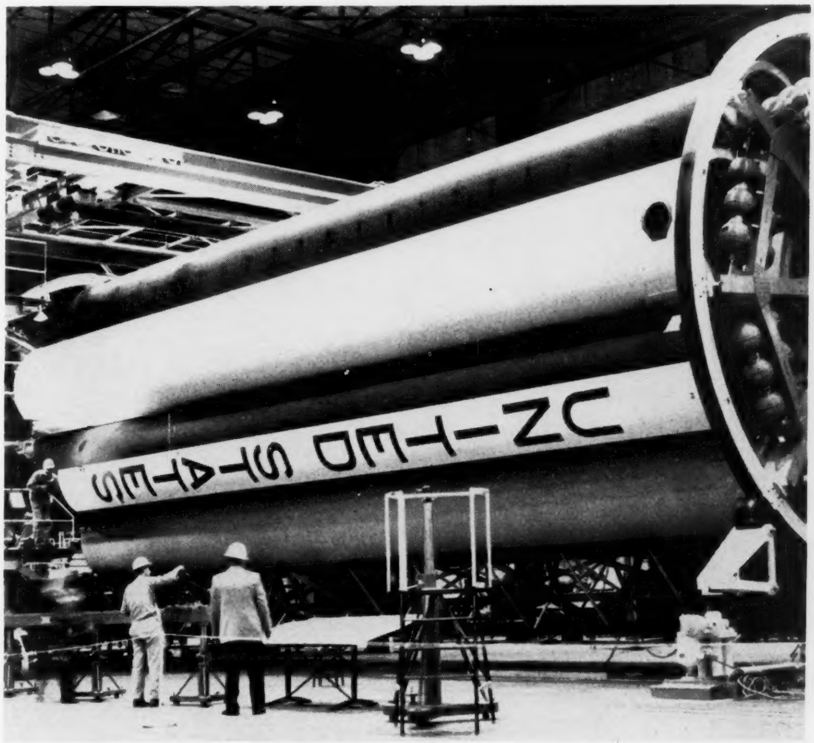
There is abundant evidence that the ionosphere is strongly affected by solar activity, and rocket-borne experiments have shown, for example, the importance of the wave-length regions studied here. Those short-duration flights have left many questions unanswered, however. 1960η2 is the first satellite, after two unsuccessful attempts, to carry instruments for these wave lengths above the dense lower atmosphere.

The observations from 1960η2 are telemetered to ground at 108.00 megacycles. After a year in orbit, the transmitter is to be shut off by ground command.

Saturn Rocket Program

MANY space science studies await completion of the Saturn rocket, which is scheduled for 1963-64. The initial version of this vehicle will be capable of boosting some 25,000 pounds into a 300-mile earth orbit, or of sending some 9,000 pounds on an interplanetary mission.

The Saturn will be a three-stage rocket,



Part of the Saturn booster stage. Spherical helium bottles at the right force fuel from nine huge tanks, four of which can be seen here. Almost 500 tons of propellants will be delivered to the eight motors in only two minutes of burning time. Redstone Arsenal photograph.

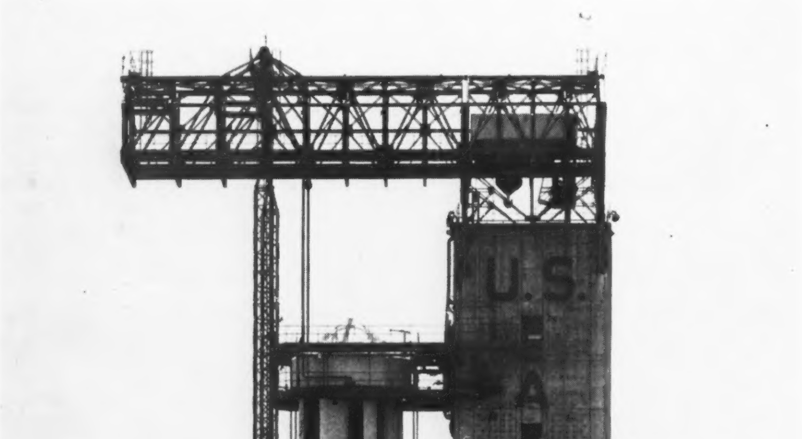
weighing more than 1,100,000 pounds and standing some 185 feet high on the launching pad. The first-stage booster rocket, which is presently undergoing static firing tests at Huntsville, Alabama, is 80 feet tall and about 22 feet in diameter. It is being designed to deliver $1\frac{1}{2}$ million pounds of thrust for two minutes, and in the test stand has already delivered a 1.3-million-pound thrust for 122 seconds.

This tremendous burst of energy is achieved with a cluster of eight H-1 engines, modified Jupiter-Thor-type engines being developed by the Rocketdyne division of North American Aviation, Inc. Four of these components are fixed in an inner square arrangement beneath the booster's huge tanks, and the others, in an outer square, are mounted on gimbals and positioned by struts that respond to the all-inertial guidance system.

The engines start up serially in opposing pairs at $\frac{1}{4}$-second intervals, and within $1\frac{1}{2}$ seconds full thrust will be built up in all eight engines, compared with the several seconds needed in other liquid-fueled rockets. Eliminated is the complex interlocking network of controls required in earlier systems.

The rocket motors will actually be triggered with rocket power. A single electric signal explodes a small solid-propellant charge to generate gas for imparting spin to the turbopump that starts the flow of fuel and oxygen. When the pressure of these reactants becomes high enough, automatic valves will pop open to admit them to the combustion chambers, and a starting charge of triethyl aluminum will also be injected.

A portion of the fuel and oxygen is to be diverted to a small gas generator that keeps the turbopump spinning, but the engine may be designed to obtain gas for this purpose directly from the main combustion chamber. The walls of the firebox are cooled by an improved system of tubing through which the reactants flow, thus permitting a flame temperature over 5,000° Fahrenheit.



One of the eight static firing tests already made on the assembled booster of the Saturn is seen here. By 1963 or 1964, the monster three-stage rocket should be ready. Redstone Arsenal photograph.

Maximum thrust is essential at the time the rocket is leaving the launching pad; therefore, the eight automatic clamps that will hold Saturn down before launching will be released only if all eight engines are operating. But within a second or so thereafter, one of the engines could fail without spoiling the mission, for that engine would immediately be shut off automatically by the explosion of a solid charge to stop the engine's turbopump. Then the vehicle could continue under power from the seven other H-1's, which would share the supply of reactants equally among them.

Liquid oxygen is carried in a central tank 105 inches in diameter, and in four of the eight outer tanks, each 70 inches across. These tanks will support the weight of the upper stages. The other four tanks, also made of aluminum but with thinner walls, carry the common supply of RP-1, the hydrocarbon fuel for all the engines.

To gain further reliability, a second engine can be cut off after the first minute of powered flight (about half the fuel supply having been used), provided three of the gimbal-mounted power plants remain operating to control the rocket's roll, pitch, and yaw. It is evident that the guidance system must be able to control a highly unstable configuration in which the distribution of weight can change rapidly. Fifty-three possible combinations of operating engines may occur!

In 830 static test firings of the H-1, Rocketdyne has found satisfactory performance some 800 times. Based on this low early rate of failures, not all of which would have meant a loss of power in an actual mission, it has been estimated that all eight engines would operate in about three-fourths of Saturn's launchings. This situation is much improved by the design that permits one, or sometimes two, engines to fail, successful launchings being expected better than 97 per cent of the time.

Instrument data from about 970 test points are being collected in the Saturn static firings and processed in a new IBM 7090 solid-state computer that can handle nearly 14 million additions a minute and is more than five times as fast as an IBM 704. As only 10 test launchings of Saturn are planned, the first to take place next year, thorough analysis of performance data must be obtained from each shot. During its development, there were about 1,200 firings of the German V-2 rocket.

No great accuracy will be required of the Saturn first-stage booster in either its position in space or velocity at power cutoff. Its function is to lift the upper stages through 20 miles or more of the dense atmosphere and to impart a speed

of only a few thousand miles per hour. Compensation for this relative uncertainty in the booster's performance will be built into the guidance system for the upper stages.

A special barge is being built to move the huge rocket from Huntsville, via the Tennessee, Ohio, and Mississippi rivers, into the Gulf of Mexico and then around to Cape Canaveral, Florida. There a 245-foot self-propelling service stand and launch complex are being readied for Saturn shots. After a launching, the booster will fall into the sea about 200 miles down-range from Canaveral. A system of retro-rockets and parachutes is being designed to break its fall, and a Navy LSD (landing ship dock) will attempt to recover the giant for later reuse of its components. Extra structural strength is provided in the booster to make this feasible.

The initial Saturn configuration will have three stages, the booster topped by S-4 and S-5 stages. In the later years of this decade it is planned to add S-2 and S-3 rocket clusters, thus producing a five-stage vehicle. S-4 is being designed by Douglas Aircraft Corp., using four Pratt and Whitney engines (from the Centaur rocket upper stage) operating on liquid hydrogen and liquid oxygen and developing 20,000 pounds of thrust apiece. The S-5, being designed by Convair, will use two of these high-performance engines.

Recently, Rocketdyne submitted the lowest bid (some 44 million dollars) to develop an engine of 200,000 pounds thrust, to be used for S-2 in a cluster of four and for S-3 in a pair. This company is also working on the F-1 engine, a single-chamber behemoth that will develop 1.5 million pounds of thrust. Used in clusters, this super-power plant may make possible manned round trips to the moon.

On July 1st, responsibility for developing the Saturn passed from the Army Ballistic Missile Agency to the National Aeronautics and Space Administration. Wernher von Braun's group, chiefly located at the Marshall Space Flight Center at Huntsville, was transferred to NASA's office of launch-vehicle programs, headed by Maj. Gen. Don R. Ostrander, USAF.

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PLANETARIUM SUMMER SHOW

"The Seven Wonders of the Universe" is the title of the current program being given at the American Museum-Hayden Planetarium in New York City. The seven objects that were selected by planetarium astronomers are: the moon, Saturn, Orion, the Crab nebula, the great globular cluster in Hercules, the entire Milky Way system, and the Andromeda galaxy. The show will be presented through September 26th.

ASTRONOMICAL SCRAPBOOK

Linne in Fact and Legend

In popular writings about the moon, the statement frequently is made, with more or less assurance, that the lunar formation Linné underwent a decided physical change during the last century. We are told how Linné was recorded as a crater by W. G. Lohrmann in 1823, by J. H. Mädler in 1831, and by J. F. J. Schmidt in 1841-43, and that Schmidt in 1866 found its place occupied instead by a white patch, which persists to this day.

The whole question of whether Linné suffered a drastic alteration a century ago hinges on what the observers of 1823 to 1843 actually saw, and the confidence their evidence deserves. Many recent appraisals of the problem seem to have been written at second or third hand, without any actual examination of the source material.

Instead, some recent writers have relied for their facts on E. Neison's well-known *The Moon,* which appeared in 1876, when much critical evidence was still unpublished. In addition, the very important analyses by W. Prinz (1894) and P. Fauth (1901) have gone generally unnoticed.

The present appearance of Linné in small telescopes is a conspicuous white spot, about six miles in diameter, lying in the eastern part of Mare Serenitatis. The spot appears smaller at lunar sunrise and sunset, and attains its maximum size about four days before and after full moon. It shrinks slightly at full. This apparent variation, repeated each month, is not peculiar to Linné, but is shared by other bright spots.

Inside this white patch, large instruments show a minute craterlet, whose diameter is under one mile according to the micrometer measurements by C. Wirtz and E. E. Barnard. The western wall of the craterlet is noticeably thicker and higher than the eastern, a fact noted by L. Brenner about 60 years ago, and since confirmed by W. H. Steavenson and several other observers. This tiny crater is much too small to have been seen as such with the modest instruments used in observing Linné in 1823-43.

The craterlet is located on the summit of a low hill, about three miles in diameter, which casts a conspicuous shadow when grazingly illuminated by the sun. From my observations of the shadow length, the hill was found to be about 300 feet high. This broad, gentle swelling deserves classification as a lunar dome, a suggestion made by Fauth and independently by H. P. Wilkins and P. Moore.

This description of the present aspect of Linné agrees in detail with Schmidt's records on about 200 nights in 1866-74. Using the 6-inch refractor of Athens Observatory, he repeatedly glimpsed the craterlet as a minute black speck within the white spot, and on several dates he saw the shadow of the hill. We have strong evidence, therefore, that Linné in 1866-74 looked the same as now.

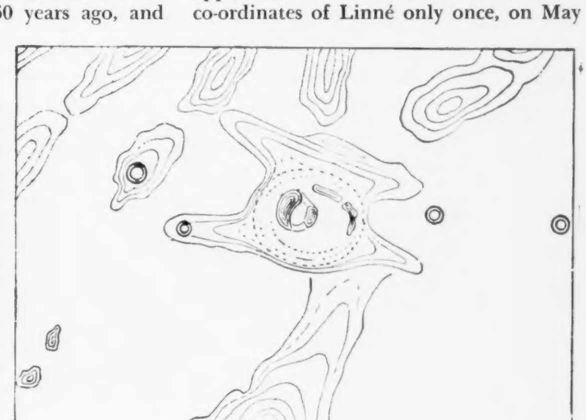
Let us next consider the crucial observations of 1823-43, by Lohrmann, Mädler, and Schmidt.

In 1821 Lohrmann, a German amateur, began preparation of a detailed lunar map, from observations with a $4\frac{1}{2}$-inch refractor. The first four of the 25 sections of this atlas were published with an explanatory text in 1824. On Section IV, Linné is depicted as a crater, labeled A.

Lohrmann on page 92 of his book tells us: "A is the second crater on this plain [Mare Serenitatis]; it lies according to my observation in longitude $+11° 27' 22''$, latitude $+27° 42' 06''$, beside a ridge extending from Sulpicius Gallus. It has a diameter of rather over one German mile [$4\frac{1}{2}$ statute miles], is very deep, and can be seen in every illumination."

We learn further from page xv of the appendix that Lohrmann measured the co-ordinates of Linné only once, on May

Philipp Fauth drew this detail chart of Linné's vicinity about the year 1906. South is above, west to the left, and one inch corresponds to 8.3 miles. The outline of the white spot is shown by dotted ellipses, within which are a craterlet and some small ridges. The contour lines are merely schematic. Reproduced from Fauth's book, "The Moon in Modern Astronomy."



Linné is drawn as a crater (left of center) in this portion of Section IV of W. G. Lohrmann's moon atlas of 1824. This reproduction is from the 1878 edition of the atlas, in which the label Linné was added by the editor, J. F. J. Schmidt.

28, 1823. He had previously chosen Conon as a reference point for charting this part of the moon, but then decided on Linné: "Conon cannot be seen distinctly near the time of full moon; **A**, on the other hand, is always visible as a bright spot in the gray Mare Serenitatis."

Except for Linné being termed a depression, these statements are quite consistent with the present appearance. The explanation of that discrepancy can be found on page 19 of Lohrmann's work: "I sketch and measure the larger mountains and craters under high illumination, so as to be able to chart in detail as large a portion as possible under the rare favorable conditions when the region is near the terminator."

These words suggest that Lohrmann's only examination of Linné may have been made under a high sun, when it would have been easy for him to mistake a bright spot for a bright crater floor. Because of this likelihood that the term "crater" resulted from an incorrect inference, no safe argument for change in Linné can be based on Lohrmann.

Mädler's observations of Linné were made jointly with W. Beer at Berlin, using a 3¾-inch refractor. Charting Linné as a crater, he describes it on page 232 of their 1837 book: "The two main ridges unite near the deep crater Linné, which according to one measure by Lohrmann and seven by us lies in longitude +11° 32′ 28″, latitude +27° 47′ 13″. It is 1.4 German miles [six statute miles] in diameter and 6° bright, but indefinitely bounded at full moon."

All seven of Mädler's positional measures of Linné were made in one night, December 12, 1831, and hence their number does not imply special attention to this formation on many dates.

There is reason to believe that Mädler made the same mistake we have ascribed to Lohrmann. Unlike modern observers, he paid particular attention to lunar features under high illumination, and he tells us explicitly that his brightness estimates were habitually so made. There are at least two other cases where Mädler charted and described as craters objects that are really bright spots: Lassell D (formerly called Alpetragius d) and Birt C. Furthermore, the verbal similarity between Mädler's and Lohrmann's accounts suggests that the earlier one influenced the later.

It remains to consider Schmidt's records of 1841-43. There is a remarkable contradiction between the two versions of them that he published. When Schmidt in 1867 announced to the Vienna Academy of Sciences the disappearance of the crater Linné, he said he had drawn this region 11 times between April 27, 1841, and August 17, 1843; only five of these drawings showed Linné, but each time as a crater. But Schmidt's book of 1878 listed 19 drawings in the same years, on at least two of which Linné was represented as a bright spot!

At the time of these observations, Schmidt was still a boy in his teens, having been born in 1825. He had not yet gained the skill and experience that were later to make him a leader in selenography, and was then using only small telescopes. For these reasons, and because of his inconsistent testimony, little weight can be attached to his 1841-43 observations.

Our survey of the Linné history reveals how weak is the evidence for supposing that this object had ever been observed as a large crater. A deeper skepticism is warranted by several very early observations of Linné as a bright spot. It is so depicted in two drawings of Mare Serenitatis made in 1788 by the English artist John Russell, as was pointed out by A. A. Rambaut in 1904. Moreover, another drawing of 1788, by J. H. Schröter, contains a light patch that is probably Linné. (This identification has sometimes been doubted, but is substantiated by Schröter's description.)

There is another line of inquiry to be traced. Mädler was still alive in 1866 when Schmidt first announced that Linné had changed. His re-examination of the formation might be expected to decide the issue. The aged selenographer was living in Germany, after having retired from the directorship of Dorpat Observatory in Russia, and was recovering from a cataract operation in April, 1866. His first opportunity to look again at Linné was on May 10, 1867, with the heliometer of Bonn Observatory. "I found it of the same form and even with the same throw of shadow as I remember seeing it 37 years before," Mädler reported.

On that very same night, Schmidt also observed Linné, with the 6-inch refractor of Athens Observatory: "Linné appeared as a conspicuous hill, casting a shadow, more striking than I have seen, at least since October, 1866. The hill may have been 3,000 feet in diameter and 500 feet high. The surrounding bright patch in the gray plain was very insignificant."

What Schmidt saw is valid today as a description of Linné just after the sun has risen there. If, then, this same appearance matched Mädler's memory of the 1830's, we have a further argument against a change having taken place.

The Linné legend turns out to have no sure foundation. Instead of repeating it, future selenography writers might more realistically call attention to this formation's scientific importance as the best-studied example of a very numerous class of bright patches, each containing a small craterlet. Other prominent instances are Lassell D, Werner D, and Posidonius γ, all three being strikingly similar to Linné. In Mare Serenitatis smaller ones are exceedingly numerous. The systematic study of these objects as a class is still a relatively untouched field.

JOSEPH ASHBROOK

REFERENCES

A full bibliography of Linné would contain several hundred titles; only a few more significant ones can be listed here.

W. G. Lohrmann, *Topographie der sichtbaren Mondoberflaeche*, Dresden, 1824.

W. Beer and J. H. Mädler, *Der Mond*, Berlin, 1837.

J. F. J. Schmidt, *Charte der Gebirge des Mondes, Erläuterungsband*, Berlin, 1878.

W. Prinz, "Have There Been Changes in the Lunar Craters Messier and Linné?" *Ciel et Terre, 14*, 32, 49, 121, 1894.

P. Fauth, "The Lunar Objects Alpetragius d and Linné," *Astronomische Rundschau, 3*, 172, 1901.

NEW KITT PEAK DIRECTOR

Nicholas U. Mayall, of Lick Observatory, has been appointed director of the Kitt Peak National Observatory in Arizona. He will assume this post on October 1st.

Dr. Mayall succeeds C. D. Shane, also of Lick and president of the Association of Universities for Research in Astronomy, Inc. (AURA), who has been the acting Kitt Peak director since the resignation of A. B. Meinel in March.

In recent years Dr. Mayall has specialized in spectroscopic studies of galaxies, an interest stimulated by his association with the late Edwin P. Hubble at Mount Wilson Observatory. The new Kitt Peak director is also known for his investigations of motions and spectra of globular clusters and planetary nebulae.

OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

A Total Lunar and a Partial Solar Eclipse in September

THE FINAL TWO eclipses of the year take place next month. The first is a total one of the moon on Monday morning, September 5th, the second a partial of the sun on Tuesday afternoon, the 20th.

The lunar eclipse will be visible from much of North America, but in the eastern United States only the opening stages can be viewed before moonset, in the morning twilight. On the Pacific Coast, however, the entire passage of the moon through the umbral shadow of the earth will be observable.

In the following timetable, adapted from the *American Ephemeris,* Pacific standard time (PST) is given. To convert this to EST, add three hours; to CST, two hours; to MST, one hour. Also, if daylight saving time is used in your community, add one hour to the appropriate standard time.

Moon enters penumbra	0:36 a.m.
Moon enters umbra	1:36 a.m.
Total eclipse begins	2:38 a.m.
Middle of the eclipse	3:21 a.m.
Total eclipse ends	4:05 a.m.
Moon leaves umbra	5:07 a.m.
Moon leaves penumbra	6:06 a.m.

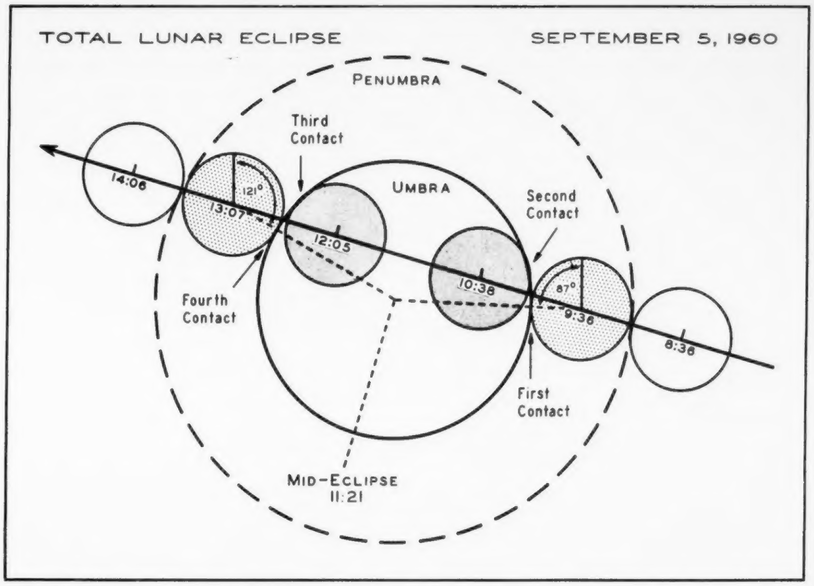
Suggestions for observations of lunar eclipses can be found in the February, 1960, issue of Sky and Telescope, page 227. While reports of color and estimates on Danjon's scale of the darkness of the mid-eclipse moon are desirable, such programs are unsafe if there is strong twilight, or if the altitude above the horizon is small.

As a guide to how much of the eclipse will be visible in different parts of the country, the table below gives standard times of moonset at various places.

Boston, Mass.	5:15 a.m. EST
Montreal, Que.	5:22 a.m. EST
Cleveland, Ohio	6:01 a.m. EST
Decatur, Ga.	6:16 a.m. EST
St. Louis, Mo.	5:38 a.m. CST
Baton Rouge, La.	5:48 a.m. CST
Tonantzintla, Mexico	6:23 a.m. CST
Denver, Colo.	5:39 a.m. MST
Mt. Palomar, Calif.	5:34 a.m. PST
Berkeley, Calif.	5:52 a.m. PST

For example, if you live in Missouri, the moon at mid-eclipse will be only a short distance above the western horizon, while a person living in Colorado will see the complete total phase, the moon setting about half an hour before last umbral contact.

The partial eclipse of the sun is the sixth in a saros series that began in 1870 and which will become annular in 2086. The maximum obscuration of the sun's diameter will be about 61 per cent, as seen from a point in the islands of northern Canada. The sun will set before eclipse begins for all places along the East Coast from Labrador to Florida, but from the Mississippi Basin westward most or all of the partial eclipse will be seen. Next month's issue will carry further information.



The moon's passage through the earth's shadow on September 5th will take place at the Universal (Greenwich) times shown here. The outer, penumbral shadow is so weak that until the moon is half immersed in it no darkening is usually noticed. The umbral shadow is much darker, and at mid-eclipse the moon may have only about 1/10,000 of its uneclipsed brightness.

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DEEP-SKY WONDERS

OBSERVERS who have access to classical amateur handbooks, such as W. H. Smyth's *Cycle of Celestial Objects* or T. W. Webb's *Celestial Objects for Common Telescopes,* are often surprised that all of the Messier objects are not listed, even though many fainter nebulae and clusters are commented on.

There are several reasons for this. Probably the most important is that these books were written in England. At a

Right: The galactic cluster M25 lies 0.8 degree south of the 5th-magnitude star at bottom center. Very recently, the distance of M25 has been independently measured as 1,860 light-years by A. Sandage and as 1,960 by H. L. Johnson. The brightest star in this cluster is the Cepheid variable U Sagittarii.

Left: The remarkable Omega nebula in Sagittarius is a rewarding sight in even small telescopes. This vast cloud of glowing gas is caused to shine by hot stars inside it. Both pictures are by the Palomar Schmidt telescope, and are reproduced on a scale of 3½ inches to one degree, with south at the top.

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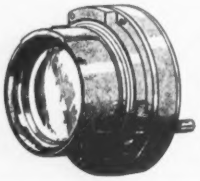

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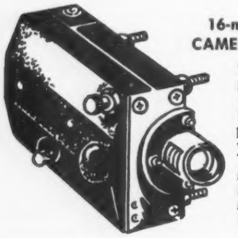

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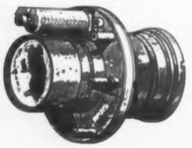

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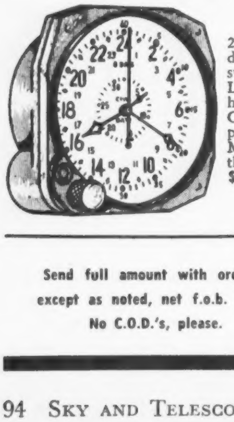

24-hr. dial and civil-date indicator. Center sweep second hand. Luminous figures and hands on black face. Case is made of black plastic. 3⅛" mounting. Manufactured by Waltham Watch Co. Price **$20.95** postpaid

8-POWER WIDE-FIELD ELBOW TELESCOPE

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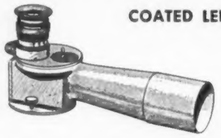

Field of view 8° 45'. Large focusing Erfle eyepiece. Eye lens diameter 2-1/16" with diopter scale +2 - −4. 4 built-in filters — clear, neutral, red, amber. Length 15⅞", width 6⅜", height 7¾", weight approx. 9½ lbs. Excellent unused condition. Price **$39.50**

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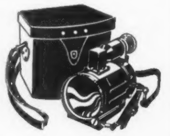

Eastman Kodak infrared receiver, formerly known as U. S. Navy Metascope, Type B. 7" long with 5" Schmidt ultra-high-speed objective lens (approx. f/0.5). Elaborate optical system, many coated lenses. Uses two pen-light batteries. Government cost, approx. $300.00. Factory-new. Shipping wt. 9 lbs. Price **$19.95**

Waterproof carrying case extra. Shipping wt. 3 lbs. Price **$3.00**

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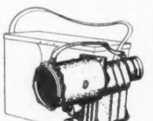

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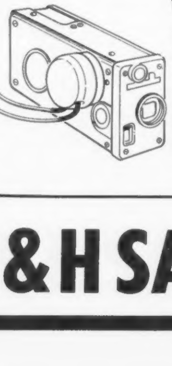

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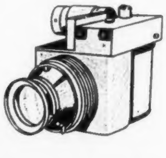

Camera weighs 26 lbs. Size: 10" x 11" x 16". Removable magazine. Picture size: 5" x 5". Diaphragm adjustment from f/2.5 to f/16. Film may be advanced manually or by 24-volt d.c. motor.

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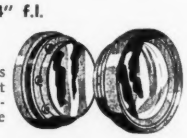
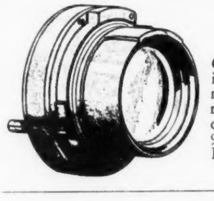


Clear diameter of front lens is 4"; rear lens is 3⅝". Set consists of two metal-mounted elements. Price **$20.00**



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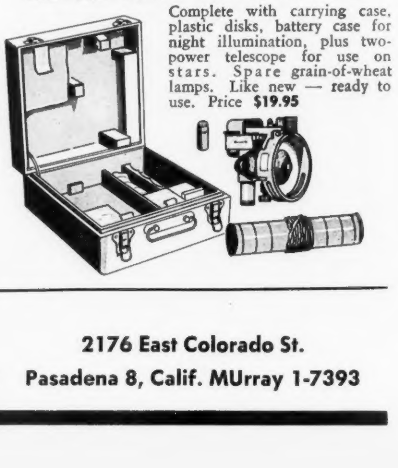

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latitude of about 52°, London is three degrees north of Paris where Messier worked. There is thus a noticeable difference in the visibility of the Scorpius-Sagittarius section of the Milky Way. Amateurs who live in the United States should, therefore, have little difficulty in viewing all the Messier objects, the southernmost of which is M7, a galactic cluster in Scorpius at declination −35°. When on the meridian at New York City, it is about 15 degrees above the horizon.

The photographs this month show two of the Messier objects in the tremendous tangle of starclouds, clusters, and dark nebulae comprising Sagittarius. M17, or NGC 6618, at $18^h\ 17^m.9$, −16° 12′ (1950 co-ordinates) is better known as the Omega or Horseshoe nebula. It covers an irregular area of 46′ by 37′ north of the Small Starcloud in Sagittarius.

Both Smyth and Webb place M17 in Scutum, or Clypeus Sobieskii (Sobieski's shield), as the constellation was once known. Visible in a finder, the Omega nebula appears "overexposed" in a richfield telescope, but becomes a most marvelous object in a 10-inch with a magnification of 80x.

Nearly a degree south of M17, well outside the field shown here, lies the open cluster M18, NGC 6613. Look halfway from the Omega nebula toward the top of the Small Starcloud. This 7th-magnitude cluster, only 7′ across, is at $18^h\ 17^m.0$, −17° 9′. Though of limited membership, containing but 12 stars according to the Skalnate Pleso catalogue, it appears quite clusterlike against one of the darker regions of the sky in this area.

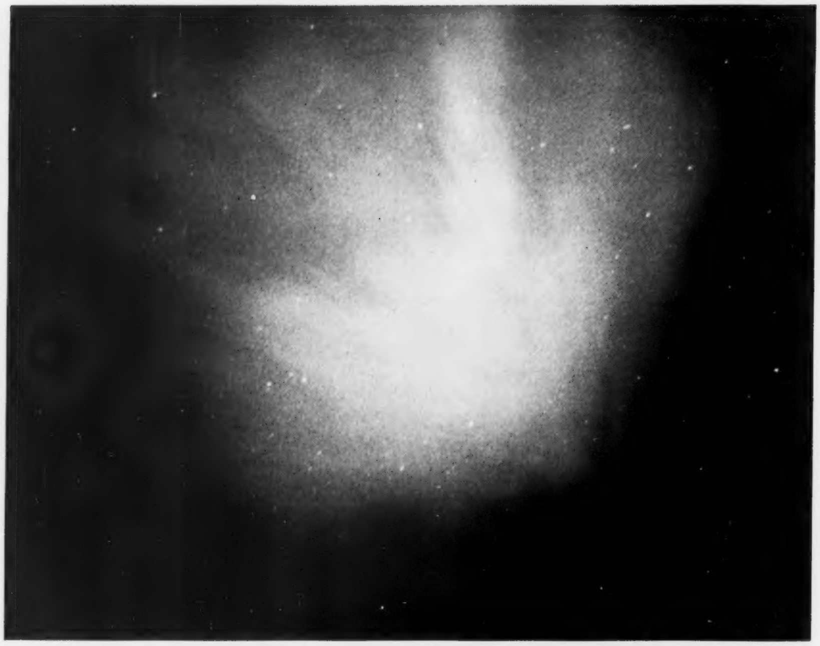
A glance at the illustration shows that cluster M25, listed as 4725 in the second *Index Catalogue,* is rather coarse and brilliant. Search for it east of the Small Starcloud, at $18^h\ 28^m.8$, −19° 17′. Covering an area slightly larger than the full moon, and containing over 50 stars, this is a conspicuous object. Rich-field instruments used under perfect seeing conditions can uncover a "ghost" of this cluster a degree to the west. Looking like a hazy sphere, the latter is hard to find visually, although it is obvious on photographs.

WALTER SCOTT HOUSTON
Rte. 3, Manhattan, Kans.

EARLY JUNE AURORAS

TWO auroras were observed on successive nights in early June. The more widely seen one was on June 3-4, observations having been made by amateurs from New York to Colorado.

At Mt. Pleasant, Pennsylvania, Robert Brosky first noticed the aurora at 12:45 a.m., Eastern standard time. By 2:15, a beautiful patch of blood-red rays appeared in the northwest about 25 degrees up the sky. At about this same time, Jack Hills, in Independence, Kansas, who had been observing Jupiter with his 8-inch reflector, noted half a dozen parallel



R. F. Newell, Jr., recorded the June 3-4 aurora with a 7-inch f/2.5 Aero-Ektar lens at 4:30 Universal time. The exposure was about 10 seconds long. The picture is centered in eastern Hercules with Corona Borealis at the right. North is toward the upper left, east toward lower left.

rays centered on the constellation Cassiopeia to the northeast, their total combined width being about 15 degrees.

Also reporting on this aurora were Raymond F. Newell, Jr., Rochester, New York; Walter A. Feibelman, Pittsburgh, Pennsylvania; Byron E. Painter, Rapid City, South Dakota; and J. R. Otoupalik, Greeley, Colorado. At Madison, Wisconsin, George W. Rippen used a new electronic tracking device to map the display.

Mr. Rippen also saw an aurora the following night; one bright homogeneous arc persisted throughout the display. Craig L. Johnson, Boulder, Colorado, took photographs of the predominantly pale green phenomenon.

SUNSPOT NUMBERS

The following American sunspot numbers for May have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

May 1, 96; **2,** 96; **3,** 102; **4,** 93; **5,** 90; **6,** 90; **7,** 105; **8,** 117; **9,** 144; **10,** 123; **11,** 126; **12,** 111; **13,** 95; **14,** 79; **15,** 89; **16,** 106; **17,** 89; **18,** 89; **19,** 92; **20,** 100; **21,** 84; **22,** 116; **23,** 129; **24,** 127; **25,** 107; **26,** 122; **27,** 118; **28,** 102; **29,** 98; **30,** 96; **31,** 95. Mean for May, 104.1.

Below are provisional mean relative sunspot numbers for June by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations at Locarno and Arosa.

June 1, 100; **2,** 90; **3,** 109; **4,** 113; **5,** 99; **6,** 109; **7,** 123; **8,** 113; **9,** 118; **10,** 147; **11,** 142; **12,** 155; **13,** 131; **14,** 131; **15,** 144; **16,** 138; **17,** 105; **18,** 91; **19,** 81; **20,** 60; **21,** 56; **22,** 50; **23,** 58; **24,** 68; **25,** 80; **26,** 99; **27,** 116; **28,** 140; **29,** 147; **30,** 165. Mean for June, 109.3.

The aurora of June 3-4 appeared quite red when W. A. Feibelman took this 15-second exposure shortly after 4:20 UT. Photographic and visual observations by Peter Schultz, Arlington Heights, Ill., recorded similar effects.

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BOOKS AND THE SKY

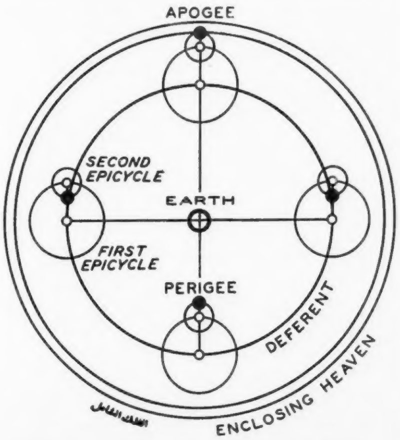
AL-BIRUNI ON TRANSITS

E. S. Kennedy, commentator. American University of Beirut, Beirut, Lebanon, 1959. 201 pages. 6.25 Lebanese pounds.

THE combined impact of three towering intellects — Copernicus, Galileo, and Kepler — after a millennium that had produced no spectacular developments — has created a widespread illusion that no worth-while astronomy existed before the 16th century. However, the "Copernican revolution" at least implies that an older astronomical concept did exist, to be swept away by the new heliocentric theory. That concept was Ptolemy's epicyclic system, frequently dismissed as a futile approach, exposed as hopelessly wrong by the Copernican theory.

What a surprise to discover that Copernicus retained far more epicycles than he rejected! In fact, his *de Revolutionibus* could be considered the ultimate in epicyclic theories. The heliocentric theory was remarkably successful in explaining the primary irregularity in planetary motion, retrogression. It eliminated Ptolemy's largest epicycle, and naturally accounted for the previously unexplained fact that the middle of a planet's retrograde motion occurs at opposition. Nevertheless, in his use of epicycles Copernicus can be considered the last of the ancient astronomers rather than the first of the new. He was strongly linked to the astronomers before him.

Today the probe into these links, the scientific background of the heliocentric theory, has become one of the most fascinating problems in the history of astronomy. Only a few years ago E. S. Kennedy and his student Victor Roberts, at the American University of Beirut, uncovered in the work of the 14th-century Damascene astronomer, Ibn al-Shatir, a lunar theory which, except for trivial differences in parameters, is identical to that of Copernicus. This model employs an epicycle revolving on another epicycle, a notion foreign to pure Ptolemaic theory. More recently, Kennedy and Roberts have found that not only in his lunar theory but in his entire planetary theory Ibn al-Shatir anticipated Copernicus, the only essential difference being that the universe of the former was geostatic rather than heliostatic.



A diagram to show how Ibn al-Shatir explained the moon's motion by a small epicycle revolving on a larger first one. The black spots indicate the moon's positions at apogee, perigee, and about midway between those times. The diagram is not to scale. Adapted from "Isis," December, 1957.

The latest publication of the Beirut group is the book reviewed here, a minor treatise on transits. Written in the 11th century by one of the most prolific Baghdad scholars, Al-Biruni, it has been translated by M. Saffouri and A. Ifram. About one-third of the new volume is taken up by the extensive commentary and analysis by Dr. Kennedy. The unique extant manuscript copy of the original Al-Biruni text is in the Oriental Public Library, Patna, India.

Al-Biruni uses the Arabic word *mamarr*, "crossing," in a more general sense than our modern "meridian transit." His treatise is a very technical explanation of these usages and is, of course, based on the epicyclic system. More rewarding than the theory itself, according to Dr. Kennedy, is the collection of by-products: "a veritable mine of numerical parameters" that can be matched with those in other manuscripts in tracing the transmission of planetary theory, and quotations from older works that have long since disappeared.

The epicyclic theory, developed by the Alexandrian scholar Claudius Ptolemy about A.D. 137, was transmitted into medieval Europe from Arabic sources, as the present name of his treatise, the *Almagest*, indicates. The question then arises: What new ideas were introduced into planetary theory by these Islamic investigators, and which of their innovations were available to Copernicus?

The principal development of Islamic astronomy spanned five centuries, from about 770, when the *Sindhind*, a treatise on Hindu astronomical theory, was translated from Sanskrit into Arabic at Baghdad, to 1252, when the Alphonsine tables were prepared in Spain. Still later, about 1450, Ulugh Beg organized his famous observatory at Samarkand.

Islamic astronomy can be roughly divided into three periods. The first, under the Baghdad caliphate, reached its peak in the 10th century. Several illustrious names are associated with this era. Thabit ibn Qurra translated the classics of Apollonius, Archimedes, Euclid, and Ptolemy, and his work was utilized by Copernicus. Al Battani (Albategnius) introduced the sine, tangent, and cotangent into trigo-

nometry, and contributed to the theory of precession. One of the greatest Arabic observers, Al Sufi, tabulated stellar magnitudes, and in his star catalogue was the first to record the Andromeda nebula. Abu-al-Wafa prepared a distinguished commentary on Ptolemy.

In the 11th and 12th centuries, astronomical studies flourished in Cairo under the Fatimids. Another great observer, Ibn Yunis, worked there, as well as Alhazen, whose study of optics influenced Kepler. The third group of Islamic astronomers constituted the 12th- and 13th-century Spanish school. Al Zarqali (Arzachel) prepared the Toledan tables, predecessors of the Alphonsine tables sponsored by Alphonso X of Castile. Also in the Spanish school were two critics of the epicyclic theory, Jabir ibn Aflah (Geber) and Al Bitruji (Alpetragius). Neither, however, was able to propose a satisfactory substitute, and their criticisms might be considered as much philosophic as astronomical. A work of Geber's was among the dozen volumes that constituted Copernicus' library.

From a general survey we might conclude that although Islamic astronomers contributed observations and developed trigonometry (an important advance), virtually no changes were made in the Ptolemaic planetary theory itself. A firm conclusion is difficult to establish, however, in view of the vast store of Islamic astronomical manuscripts yet untouched by modern scholars.

As shown by the work of Dr. Kennedy and his associates, the treasure house of medieval astronomical documents is now being explored, and the background to the scientific advances of the Renaissance is becoming known in richer detail. But the general reader will probably find this book far too specialized to hold his interest. In the absence of any recent synthesis of Islamic astronomy, one could examine J. L. E. Dreyer's *A History of Astronomy from Thales to Kepler* (recently reprinted in a paper-bound edition).

Those who wish to purchase *Al-Biruni on Transits* may order it at $2.00 per copy from Khayat's Bookstore, 23-24 Rue Bliss, Beirut, Lebanon.

OWEN GINGERICH
Harvard Observatory

PROPERTIES OF DOUBLE STARS

Leendert Binnendijk. University of Pennsylvania Press, Philadelphia, 1960. 349 pages. $12.50.

OBSERVATIONS of binary stars have yielded vital astrophysical information about stars in general, often providing data that are difficult or impossible to obtain in any other way. To double stars we owe especially our knowledge of stellar masses and densities, and they have helped tremendously in studies of star distances, luminosities, temperatures, sizes, atmospheres, and interiors.

Both the observations and their analysis and interpretation are important, and the student proficient in this subject has necessarily learned a great deal of general astronomy. Astrometry, spectroscopy, photometry, the reduction of observations, numerical analysis, are all involved. Perhaps more important, such a student has become acquainted with stars that have made astronomical history; for example, the white dwarf companion of Sirius and the sextuple system of Castor.

A course in binary stars is therefore peculiarly profitable for a senior or beginning graduate student in astronomy, provided it covers more than binary star orbit theory. I plan to use this book as the primary reference in a binary star course this fall at Indiana University. Leendert Binnendijk's work is especially suitable, because his treatment goes so far beyond the mere discussion of various methods of orbit determination.

The chapters on visual double stars, spectroscopic binaries, and eclipsing variables are preceded, respectively, by long chapters on astrometry, spectroscopy, and photometry. But the author has included much other material. For instance, he treats parallaxes of all kinds: trigonometric, secular, dynamical, spectroscopic,

and cluster. He covers the method of dependences for the reduction of photographic star positions. The mass-luminosity law and the Cepheid period-luminosity law are both discussed, as are the H-R diagram and even galactic rotation. Thus, the book's title might be considered to be somewhat misleading, and the subtitle equally so, for it reads: "A Survey of Parallaxes and Orbits."

The book is based on lectures given by the author in a year's advanced class for students who had a descriptive course in astronomy and who had the necessary basic knowledge in physics and mathematics. In my opinion it is very readable, easily understood by the above-average senior student, yet as technical as is necessary for the material it covers.

There is a lengthy but well-selected bibliography at the end of each chapter. However, some definitions are not rigorously given and more careful editing of the sentence structure would be desirable.

In comparison with the famous work of three decades ago, *The Binary Stars,* by Robert G. Aitken, Binnendijk's book is much stronger in astrometric binaries, long-focus photographic astrometry, photometry, and eclipsing binary theory. But Aitken's volume provides useful supplementary reading, as do three appropriate chapters in both J. A. Hynek's *Astrophysics* (1951) and Vol. 50 of the *Handbuch der Physik* (1958).

For a course of the kind I have in mind, a number of topics should be added to the Binnendijk treatment. These include the two-body problem, numerical solutions of actual orbits, least-squares theory with numerical applications, E. King's standard velocity curves, and the method of O. C. Wilson for double-line binaries, using for many topics actual case histories. I would carry through the discussions for such interesting specimens as Epsilon and Zeta Aurigae, Sirius, Algol, Castor, Beta Lyrae, Alpha Centauri, Nova DQ Herculis, Procyon, and Lalande 21185.

There is one statement in this book to which I must take strong exception, on page 47: "This catalogue [the Yale catalogue of parallaxes] is very important because all other distant measurements are indirect and have to be calibrated with the trigonometric parallaxes. Thus the trigonometric parallaxes form the basis of all distances measured in the universe."

But consider the Hyades cluster, whose distance is well determined from the convergence of its members' proper motions and their radial velocities, or the Crab nebula, which has a shell expanding at a known rate (from spectroscopic measures) so its angular rate of expansion is an indicator of distance. We have no good trigonometric parallax of a Cepheid variable, yet the zero point of the period-luminosity law has been found statistically from the components of proper motions of nearby Cepheids. Then these yard-

sticks of the universe are used directly or indirectly for all really large (intragalactic and intergalactic) distance estimates. This is a not insignificant number of instances where distances are determined independently of trigonometric parallax determinations.

JOHN B. IRWIN
Goethe Link Observatory
Indiana University

NEW BOOKS RECEIVED

PHYSICS AND MEDICINE OF THE ATMOSPHERE AND SPACE, *Otis O. Benson, Jr.*, and *Hubertus Strughold*, editors, 1960, *Wiley*. 645 pages. $12.50.

Forty-two papers are published from a symposium on November 10-12, 1958, at San Antonio, Texas. The chapters of primarily astronomical interest are: 3, meteoritic material in space (F. L. Whipple); 37, solar physics (W. O. Roberts); 38, the moon and planets (G. P. Kuiper); and 39, Mars (G. de Vaucouleurs).

MAN HIGH, *David G. Simons* and *Don A. Schanche*, 1960, *Doubleday*. 262 pages. $4.50.

This is Lt. Col. David G. Simons' personal account, written in collaboration with a *Life* reporter, of his balloon ascent in August, 1957, to a height of 102,000 feet. The highly dramatized narrative is intended for the general reader.

PHYSICAL GEOGRAPHY, *Arthur N. Strahler*, 1960, *Wiley*. 534 pages. $7.50.

Now in its second edition, this well-illustrated college textbook describes the various kinds of structural features of the earth's surface, and explains their origin and evolution. Cartography, weather, and tides are among other topics discussed. There is an extensive bibliography.

THE UNIVERSE OF LIGHT, *Sir William Bragg*, 1959, *Dover*. 283 pages. $1.85, paper bound.

This is a reprint of a book based on Sir William Bragg's Royal Institution lectures in 1931, explaining in popular language the nature of vision and the properties of radiation.

RADIATIVE TRANSFER, *S. Chandrasekhar*, 1960, *Dover*. 393 pages. $2.25, paper bound.

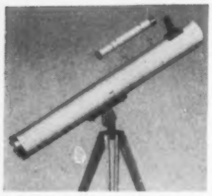
Originally published by the Oxford University Press in 1950, this important technical treatise on the behavior of radiation in stellar and planetary atmospheres is now available in reprint form.

DIE ENTSTEHUNG VON STERNEN, *G. R. Burbidge, F. D. Kahn, R. Ebert, S. von Hoerner*, and *S. Temesvary*, 1960, *Springer-Verlag*, Heidelberger Platz 3, Berlin-Wilmersdorf, West Germany. 330 pages. DM 38.

The formation of stars by condensation from interstellar matter is the subject of three prize-winning essays in this volume, which together summarize present knowledge of the origin of stars and star groups. The contributions by Drs. Burbidge and Kahn are in English, while the one by the other three astronomers is in German.

AEROSPACE DICTIONARY, *Frank Gaynor*, 1960, *Philosophical Library*. 260 pages. $6.00.

Brief, elementary definitions are given for about 1,500 terms used in space exploration. The coverage of astronomical terminology is slight.



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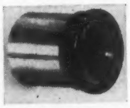

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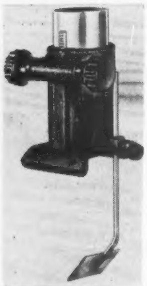

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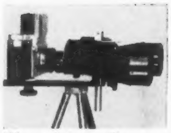

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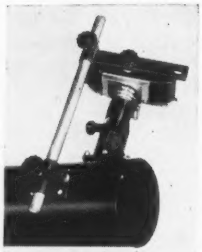

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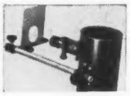

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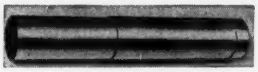

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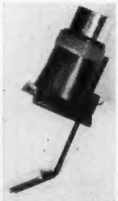

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Stock #60,049-Y (diagonal holder) **1.00**

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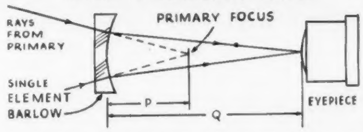

WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q.

Beautiful chrome mount. We now have our Barlow lens mounted in chrome-plated brass tubing, with special spacer rings that enable you easily to vary the power by sliding split rings out one end and placing them in other end. Comes to you ready to use. Just slide our mounted lens into your 1¼" I.D. tubing, then slide your 1¼" O.D. eyepieces into our chrome-plated tubing. Barlow lens is nonachromatic.
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These lenses are made for telescopes that have smaller diameter eyepieces than the standard 1¼" size. Mount one between the eyepiece and objective, and triple your power. Instructions included. Single-element lens, focal length −1-5/16", unmounted.
Stock #30,185-Y....0.932" diam...........$3.50 ppd.
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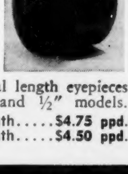

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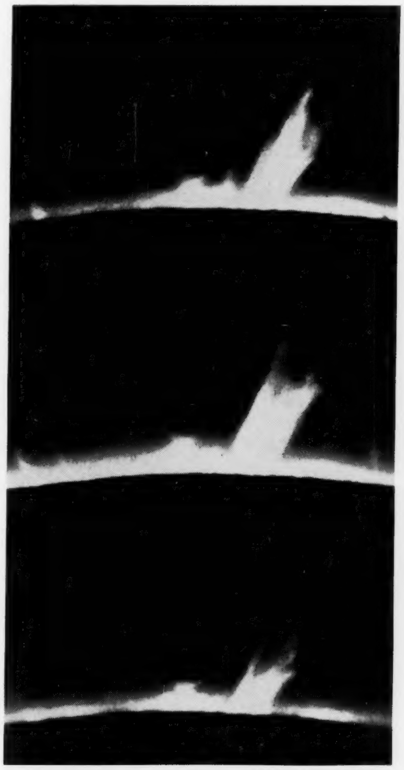
A Solar-Prominence Telescope Using an Interference Filter

THE PROMINENCES on the sun afford some of the most fascinating viewing in the sky, and doubtless many amateur astronomers would observe them if it were not for the instrumental problems involved. Except for the rare, brief moments of a total solar eclipse, prominences cannot be seen without a spectrohelioscope, coronagraph, or quartz birefringent filter.[1]

The first of these instruments has been used for many decades, but a spectrohelioscope is difficult to make and operate and is better suited to study of the solar surface. The coronagraph simulates an artificial eclipse, but is so sensitive to scattered light that it can be most efficiently employed only in selected high-altitude locations. Like the spectrohelioscope, the quartz birefringent filter removes all the light except that of the hydrogen-alpha line in the red region of the spectrum, at a wave length of 6563 angstroms. This filter gives excellent results, but is also difficult to make and demands close temperature control during use.[2]



On June 14, 1959, Dr. A. K. Presnell recorded this very bright, rapidly changing surge prominence on the limb of the sun. He took these views at 1:49, 1:53, and 1:59 p.m., Eastern standard time (top to bottom). The enlargement is some four times from the original 35-mm. negative, and the greatest extent of the prominence is about 60,000 miles. The telescope used for these pictures is described here.

Here I wish to describe another type of filter that may be employed with modified telescope optics to give satisfactory observing. It works on the principle of the interference of light. When a beam passes through two closely spaced plane-parallel surfaces, part of the light is reflected by the second surface back to the first one, where it is again reflected to become part of the transmitted beam. Some wave lengths of light will be reinforced and others more or less canceled out by interference of the two sets of waves, which are no longer in phase. The amount of interference at a particular wave length depends on the spacing of the surfaces and the nature of the material between.

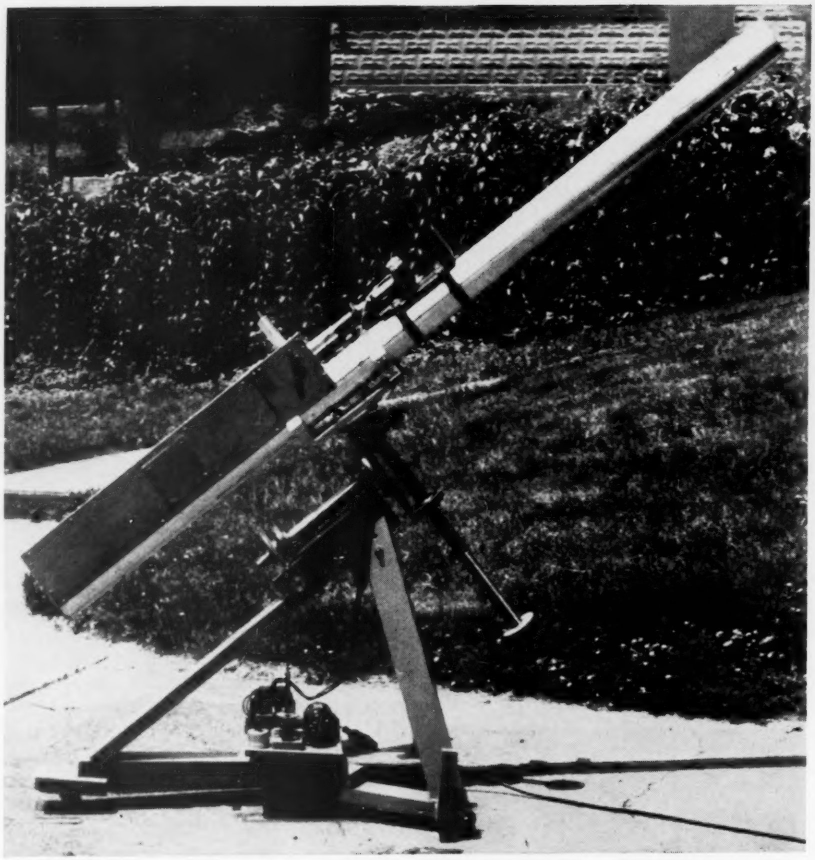
Therefore, by proper choice of materials and spacing, a filter can be made that will reflect or transmit with high efficiency a spectral band at any desired wave length. For a number of years such filters have been available commercially, but their transmitting bands usually have a half-width of about 150 angstroms, much too wide for solar prominence work.

Recently, however, Baird-Atomic, Inc., succeeded in producing a multilayer interference transmission filter two inches in diameter with a half band-width of five angstroms, centered on the Hα line. This is probably the optimum band-width, for the line itself has considerable breadth, and Doppler motions in the prominences often shift the radiation from the center of the line.

This filter has the great advantage of transmitting over 50 per cent of the incident energy at the peak of the transmission band, compared to about six per cent for a quartz monochromator. Considering the shopwork and labor saved, such filters are not expensive,[3] and pictures I made last year using a prototype filter show how well it is adapted for solar work, even in the relatively unfavorable observing conditions of the Middle West.

At first the filter was mounted in front of the prime focus of the Cincinnati Astronomical Society's 8-inch refractor, which was stopped down to a 2-inch aperture. An occulting disk, to block out the sun's bright disk but not the prominence region at the limb, was placed at the telescope's focus. Reasonably good results were obtained, but adapting an ordinary telescope in this way is not recommended. For one thing, there is considerable scattered light from the four surfaces of the achromatic objective. Since the Hα filter is practically monochromatic, a single-element lens can give excellent images, while scattering less light.

Later the filter was mounted in a sta-

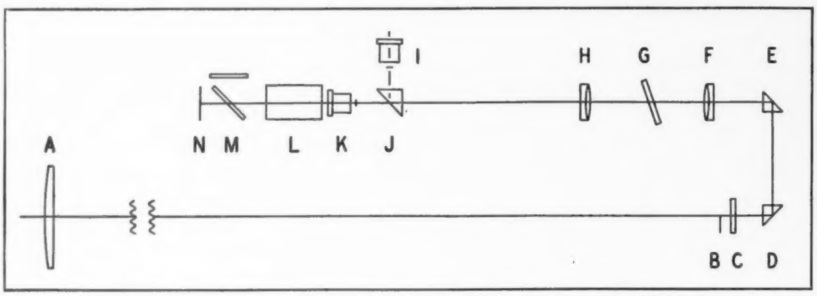


The Presnell solar prominence telescope and its mounting. The plano-convex lens is carried at the upper end of the tube, while the camera is just above center. The eyepiece for visual observations extends toward the upper left in this view. At the center of the base are the drive mechanism and gears. A reversible motor and differential provide slow motion in right ascension.

tionary telescope pointed at a coelostat. But the first-surface mirrors scattered light, and a back-surfaced wedge-shaped mirror made the image of the sun slightly elliptical, so it did not match the occulting disk. After these experimental efforts, I decided upon the optical system sketched here, which proved far the best.

Light enters at the left, where **A** is a simple plano-convex lens, stopped down to a 3-inch aperture, with a focal length of 90". It is movable for focusing, so that other parts of the optical system, such as the occulting disk at **B**, may be kept stationary. This disk is rotatable around the optical axis. Since the earth's distance from the sun varies during the year, the solar image changes size, and I have disks of different radius that are interchangeable. There are three light baffles or diaphragms between the objective and the occulting disk, in order to cut down scattered light.

At **C**, 3" behind **B**, is a polished Corning sharp-cutoff filter No. 2412, which passes only red light. This is necessary because the interference filter transmits several broad bands in the blue end of the spectrum. Immediately behind this red filter is the right-angle prism **D**, while another is 4½" away at **E**, reducing the length of an otherwise inconveniently



A schematic diagram of the prominence telescope's optical system. Light enters the lens at A and is viewed at I or photographed at N.

Enlarged about eight times, this film frame shows a looped prominence and associated surface activity. It was taken June 19, 1959, at 5:31 p.m., EST. All photographs with this article are provided by the author.

long optical system by folding the light path.

The light then passes through **F,** a collimating lens of 21″ focus. A much shorter focal length should not be used, as it would seriously limit the size of the field. I use a war-surplus achromat, but a single-element lens would be satisfactory. Next, at **G,** is the interference filter itself, with provision for adjusting it about an axis perpendicular to the optical axis. This is necessary because the wave length transmitted by a filter of this type is a function of the angle of incidence, and very slight changes in the desired angle may take place over a period of years.

After the filter, at **H,** is another lens identical to the collimator. When constructing the telescope, I left enough space between **F** and **H** to substitute a quartz monochromator if desired, but such a change is no longer contemplated. Lens **H** brings the light to a focus at the photographic eyepiece, **K,** but the beam may be diverted by swinging the hinged prism **J** into place when the visual eyepiece at **I** is to be used. Following the photographic eyepiece is a single-lens reflex 35-mm. camera fitted with a lens of 6″ focal length. The camera body is represented at **L,** while **M** shows the flip mirror that permits viewing the image on the ground-glass screen above it just before a picture is taken.

On March 22, 1959, at 11:05 a.m., EST, this relatively faint, high-level prominence was photographed.

The film is at **N,** upon which falls a portion of a $3\frac{1}{2}''$ image of the sun. As the solar diameter is 865,000 miles, and its image is about 89 millimeters across, my film scale is nearly 10,000 miles to the millimeter.

The occulting disk design presented some mechanical problems, my arrangement being, perhaps, more complicated than necessary. Each disk is made of thin brass with a beveled edge, mounted on a small steel arm hinged to a diaphragm. Two brass rings inside the telescope tube hold the diaphragm in place, while one of the rings fits a raised section on the diaphragm to prevent radial shifting. A slot in the tube, between the rings, allows

the diaphragm's knurled edge to be rotated by a finger, so the attached disk may be oriented to correspond to the portion of the sun's limb being observed.

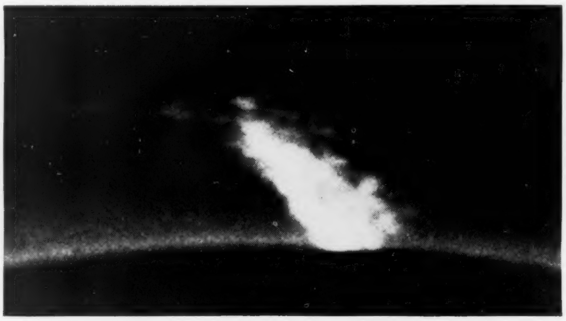
A small hole in the telescope tube gives access to a screw that adjusts the radial displacement of the occulting disk and steel arm. If the disk is centered and a very low-power eyepiece is used, the entire circumference of the sun may be seen at one time.

Made of aluminum tubing and magnesium sheet, the telescope weighs only 23 pounds, which facilitates taking it indoors for storage. It is readily removed from the mounting, to which it is fastened by luggage clamps. The mounting tripod can be moved on retractable wheels and set on three small brass plates in the concrete of my driveway. It works well enough except in high winds, but the greater rigidity of a pier would aid in maintaining exact superposition of the occulting disk on the sun's image.

For slow motion in right ascension, a reversible motor is connected through a differential to the synchronous drive. Motion in declination is imparted by a hand-driven worm. The differential is war-surplus, the other gears having been cut on a lathe. Both axes have slip clutches for rapid pointing of the instrument.

The visual performance of the telescope is excellent, very fine detail being readily observable. On the rare occasions in this locality when there is only a little haze, the prominences appear quite bright against a dark background. In the absence of some microscopic pinholes that marred the prototype filter, the contrast should be as good as that with a high-quality birefringent filter. Sometimes when the scattering by haze is small, I can observe prominences through thin clouds.

My photographic results have not been as good as the visual because of difficulties in focusing, as well as graininess and lack of contrast in the film. I found that a thin coat of colorless nail polish remarkably improved the rather coarse ground-glass screen of the camera. A much finer surface is desirable to permit sharp focusing. After many trials I have settled on Eastman's red-sensitive 103-Hα emulsion, which is available only in 100-foot rolls in the 35-mm. size, with delivery taking about six weeks.



On June 13, 1959, at 2:07 p.m., EST, this prominence was observed on the sun with the interference-filter solar telescope described in this article. The author uses Kodak 103-Hα film developed in D-19.

This very sensitive film, developed in D-19, and the high efficiency of the interference filter allow exposures on prominences as short as 1/50 second. This is a great help when there is much wind.

To avoid annoying ghost images, the two outer glass surfaces of the filter should have been antireflection coated by the manufacturer. Visible only if a portion of the sun's image is not covered by the occulting disk, the ghosts are not too annoying for visual work, but look very bad on photographs.

A. K. PRESNELL
3315 Queen City Ave.
Cincinnati 38, Ohio

NOTES

1. Spectrohelioscopes are described on page 192 of *Amateur Telescope Making—Book I*, and a quartz birefringent filter in the pamphlet by Richard B. Dunn, *How To Build a Quartz Monochromator for Observing Prominences on the Sun.* Also see *ATM—III*, page 376.
2. For details of an instrument similar to Dr. Presnell's but using a quartz monochromator, see "Construction of a Solar Telescope," by Walter J. Semerau, SKY AND TELESCOPE, May, 1958, page 369.
3. Baird-Atomic, Inc., 33 University Rd., Cambridge 38, Mass., has stock Hα filters of two types, B-11 and B-12, in sizes 1″ and 2″ square. Type B-11, with a transmission of 50 to 60 per cent, has a broader band-width than B-12, for which the transmission is 25 to 40 per cent. B-11 costs $135.00 for the 1″ size, $200.00 for the 2″; B-12 is $250.00 and $375.00, respectively.

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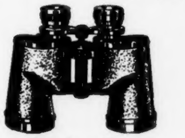

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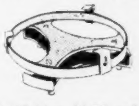

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NEW! **80-mm. Objective**

Big 80-mm.-diam. (3⅛") objective, for spotting or astronomical use. Will show stars of the 11th magnitude — 100 times fainter than the faintest visible to the naked eye. Table-top tripod included, extended 18", closed 13¼". Length of scope 16¼". Combined weight of scope and tripod is 5¼ lbs.

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Power	Field at 1,000 yards	Exit pupil diam.	Relative Brightness
15x	122 ft.	5.4 mm.	29
20	122	4.0	16
30	61	2.7	7
40	49	2.0	4
60	32	1.3	1

Cat. No. S2052 .... **$59.50 ppd.**

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These mirrors are of the highest quality. Aluminized and silicon-monoxide protective coating. You will be more than pleased with their performance.

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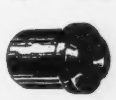
S1507	Pyrex	6"	60"	25.00
S2188	Pyrex	6" parabolic	48"	49.50

Mounted Eyepieces



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Cat. No.	F.L.	Type	ppd.
S2192	6 mm. (¼")	Orthoscopic	$13.25
S1851	6 mm. (¼")	Ramsden	4.75
S1853	12.5 mm. (½")	Ramsden	4.50
S1207	12.5 mm. (½")	Symmetrical	6.00
S1251	16 mm. (⅝")	Erfle (wide-angle)	12.50
S1257	16 mm. (⅝")	Orthoscopic	12.50
S1209	18 mm. (¾")	Symmetrical	6.00
S1211	22 mm. (27/32")	Kellner	6.00
S1835	27 mm. (1-1/16")	Kellner	4.50
S1355	32 mm. (1¼")	Plossl	12.50
S1253	35 mm. (1⅜")	Symmetrical	8.00
S1255	55 mm. (2-3/16")	Kellner	6.00
S1485	56 mm. (2¼")	Symmetrical	6.00

COATED LENSES 75 cents extra.

"Giant" Wide-Angle Eyepieces

Erfle eyepiece with 65° field, contains 3 coated achromats. 1½" E.F.L., clear aperture 2⅛". Has a focusing mount with diopter scale. Also makes an excellent 35-mm. Kodachrome viewer, magnifies seven times.

Cat. No. S1405 (Illustrated) ....**$12.50 ppd.**
Cat. No. S1858 Same as above without diopter scale .... **9.95 ppd.**
Cat. No. S1594 1¼"-diam. ADAPTER for eyepieces above .... **3.95 ppd.**

Wide-Angle Erfle

Brand-new eyepiece with 68° field; coated. E.F.L. 1¼". Focusing mount, 3 perfect achromats, 1-13/16" aperture.

Cat. No. S1020 ....**$13.50 ppd.**
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An Economical Eyepiece

This mounted eyepiece has two magnesium-fluoride-coated achromatic lenses 29 mm. in diameter. Excellent definition. E.F.L. 1¼". Cell fits 1¼" tubing.

Cat. No. S1911 Coated ....**$5.90 ppd.**
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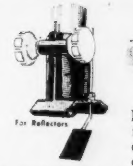

For Reflectors

For Refractors

Here is a wonderful opportunity for you to own a most mechanically perfect Rack-&-Pinion Focusing Eyepiece Mount with variable tension and adjustment. Will accommodate a standard 1¼" eyepiece, positive or negative. The body casting is made of lightweight aluminum with black-crackle paint finish, focusing tube of chrome-plated brass. Focusing tube for refractors has a travel of 4", for reflectors 2", and will fit all size tubing.

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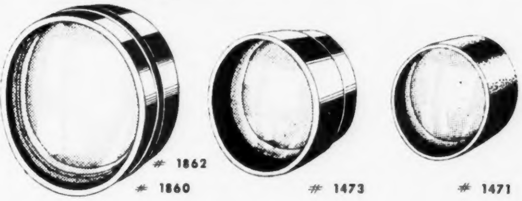

Each lens is thoroughly tested and guaranteed to resolve to Dawes' limit. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cells are machined to close tolerances so that they fit directly over or into our standard aluminum tubing, eliminating any mounting problems. Test a lens, or have any qualified person test it; we are certain that you will be satisfied. If not, take advantage of our money-back guarantee. *We offer the lowest-priced, hand-corrected, precision, American-made astronomical objective,* mounted in an aluminum cell. Our reputation for high-quality lenses has established us as the most reliable source in the industry.

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4⅛" APERTURE f/15 — 62" F. L.	Cat. No. S1472	NOT COATED	$60.00 ppd.
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6" APERTURE f/10 — 60" F. L.	Cat. No. S1861	UNMOUNTED	$150.00 ppd.
	Cat. No. S1860	MOUNTED	175.00 ppd.
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	Cat. No. S1862	MOUNTED	175.00 ppd.

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S1112	(2⅛")	(11¾")	12.50
S1110	(2⅛")	(13")	12.50
S-958	(2⅛")	(15½")	9.75
S1145	(2⅛")	(20")	12.50
S-952	(2⅛")	(23½")	12.50
S1431	(2⅛")	(30")	12.50
S1432	(2⅛")	(40")	12.50

Cat. No.	Diam.	F.L.	ppd.
S1520	(2⅛")	(50")	$12.50
S-851	(3-1/16")	(15")	21.00
S1158	(3⅛")	(19½")	28.00
S-822	(3-3/16")	(24½")	22.50
S1092	(3¼")	(26")	28.00
S1093	(3¼")	(28")	28.00
S1139	(3¼")	(30")	28.00
S-955	(3¼")	(34½")	28.00

Cat. No.	Diam.	F.L.	ppd.
S-957	(3¼")	(40")	$30.00
S1155	(4")	(34½")	60.00
S1460	(4¼")	(36")	60.00
S1159*	(4⅜")	(42")	60.00
S1225	(4⅜")	(42")	67.50
S1474*	(5-1/16")	(24¾")	75.00
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CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

OCCULTATIONS OF THE HYADES AND OF ALDEBARAN

On the morning of Monday, August 15th, the moon will occult 4th-magnitude Gamma Tauri for observers in the eastern part of the United States. This star is located at the tip of the V-shaped Hyades cluster. The moon will be 22.6 days old, so disappearance will be at the bright limb, reappearance at the dark.

At station **A** (Massachusetts), the disappearance is at 3:26 a.m., Eastern daylight time, in position angle 79°; the star will emerge 73 minutes later, position angle 248°. Station **B** (Montreal) has times of 3:30 a.m. EDT, 71°, and 4:43, 256°, for immersion and emersion, respectively; **C** (Washington, D. C.), 3:17, 82°, and 4:27, 244°; **D** (Toronto), 3:24, 70°, and 4:34, 258°; and **F** (Illinois), 2:15 a.m., Central daylight time, 67°, and 3:19, 261°.

For the rest of the country the disappearance occurs below or too near the horizon. The reappearance will, however, be visible at stations **G, H,** and **J** (central Texas, Denver, and Edmonton). The times and position angles are: **G,** 3:02 a.m., CDT, 247°; **H,** 2:13 a.m., MDT, 273°; and **J,** 2:24 MDT, 311°.

Nearly 10 hours after the occultation of Gamma Tauri, the moon will cover Aldebaran, at midday on August 15th. While no occultation will occur at stations **A, B,** or **J,** skillful telescopic observers elsewhere may see the now 22.9-day-old moon cover this 1st-magnitude star. Times and position angles for immersion and emersion are:

C, 2:06 p.m. EDT, 35°, and 2:41, 321°; **D,** 2:14, 6°, and 2:22, 350°; **F,** 12:56 CDT, 47°, and 1:45, 309°; **G,** 12:54 CDT, 83°, and 2:01, 273°; **H,** 11:42 a.m. MDT, 59°, and 12:45, 295°; **I,** 11:39 a.m. MDT, 81°, and 12:53, 274°; **K,** 10:19 a.m. PDT, 78°, and 11:41, 272°; **L,** 10:18 PDT, 55°, and 11:28, 294°; **M,** 10:24 PDT, 25°, and 11:05, 323°.

West Coast watchers will also have a chance to see the moon cover θ^1 Tauri (**K, L, M**) and θ^2 Tauri (**L, M**). The reappearance from behind the moon of 70 Tauri will be visible from stations **K, L,** and **M,** and of 71 Tauri at **M.** A map showing the positions of these stars was printed on page 380 of the April, 1960, issue; the four stars are labeled there 669, 671, 659, and 661, respectively.

Detailed information on all of these occultations was printed in the December, 1959, issue, pages 99-106, together with information on predicting the times for one's local station.

AUGUST METEORS

This is the month of the famous Perseid meteors, which attain an hourly rate of about 50 under favorable conditions. The moon will interfere this year, however, for it reaches full phase on August 7th and last quarter on the 14th. The Perseids have about a 10-day duration, with maximum of the shower on August 11-12. Although the number of meteors seen will be very much reduced by moonlight, some bright Perseids may repay the patient observer.

W. H. G.

MOON PHASES AND DISTANCE

Full moon	August 7, 2:41
Last quarter	August 14, 5:37
New moon	August 22, 9:16
First quarter	August 29, 19:23
Full moon	September 5, 11:19

August	Distance	Diameter
Perigee 5, 20ʰ	223,500 mi.	33′ 13″
Apogee 18, 1ʰ	252,000 mi.	29′ 28″
September		
Perigee 2, 21ʰ	226,300 mi.	32′ 48″

MINIMA OF ALGOL

August 1, 23:38; 4, 20:27; 7, 17:16; 10, 14:04; 13, 10:53; 16, 7:41; 19, 4:30; 22, 1:18; 24, 22:07; 27, 18:55; 30, 15:44.

September 2, 12:33; 5, 9:21; 8, 6:10.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of the star's least brightness.

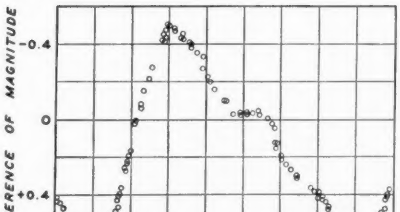
ETA AQUILAE

One of the brightest and most easily observed variable stars in the sky is Eta (η) Aquilae, which can be identified with the aid of the star chart on page 117 of this issue. This variable is of the Cepheid type, and runs through its cycle of changes in a period of 7.18 days.

Its brightness variation is conspicuous to the naked eye for anyone who views the star night after night. When brightest, Eta is approximately equal to Delta (δ) Aquilae, magnitude 3.4. Then, during the next five days, it fades until it approximately matches Iota (ι) Aquilae, magnitude 4.3. Only two days are needed for the increase to the next maximum. During this August, maxima of Eta Aquilae take place on the 7th, 14th, 22nd, and 29th.

The pattern of light change is shown in detail by C. C. Wylie's photoelectric light curve. Because his measurements were made in blue light, he found a larger range in magnitude than is observed visually, as the amplitude is greater at shorter wave lengths. Note the marked hump on the descending part of the light curve, a feature typical of Cepheids with periods of seven days.

An English amateur, Edward Pigott, discovered the variability of Eta Aquilae as early as the year 1784. Since then, the light variations have repeated themselves with great faithfulness for nearly 10,000 cycles, except for a slight increase in length of period. Around the year 1800 this was 7.1763 days, in 1870 about 7.1765 days, and it is now 7.1766 days, according to P. P. Parenago. Although this period increase is small, its effect is cumulative, and in the course of a lifetime it can shift the times of maximum by half a day.



Eta Aquilae's light curve, as determined by C. C. Wylie at the University of Illinois Observatory. He measured the magnitude difference between the star and one of constant brightness. Adapted from Baker's "Astronomy."

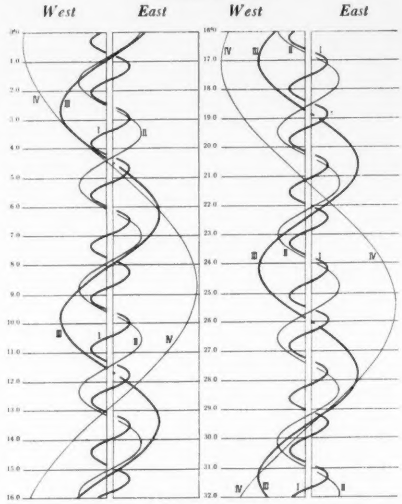
JUPITER'S SATELLITES

The curves in the accompanying chart show the positions of Jupiter's four bright moons, as seen in an inverting telescope, with north at the bottom and east at the right. Each horizontal line is for 0ʰ Universal time on the date specified, and the intersections of the line with the curves indicate the places of the satellites at that time. For other Universal times, interpolate between the 0ʰ lines. The double vertical lines represent the planet's disk.

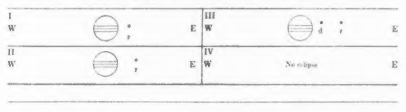
The lower section is intended to aid observations of the eclipses of Jupiter's moons; *d* is the point of disappearance of the satellite in Jupiter's shadow, *r* is the point of reappearance. The chart is from *The American Ephemeris and Nautical Almanac;* for further explanation, see page 446 of SKY AND TELESCOPE for May, 1960.

JUPITER'S SATELLITES IN AUGUST

UNIVERSAL TIME

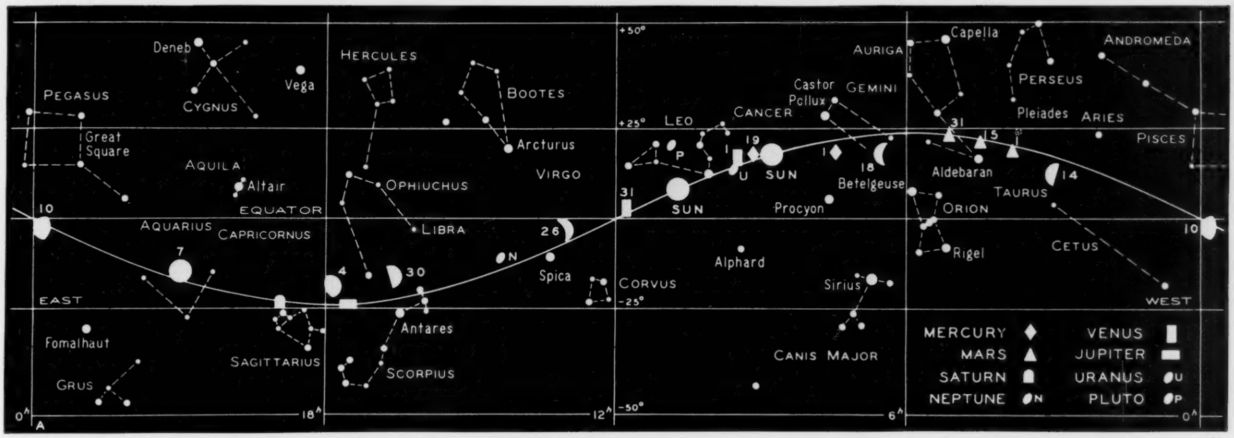


PHASES OF THE ECLIPSES



CORRECTION

In last month's issue, page 17, third column, fifth paragraph, line five, read "Leghorn, Pisa, Arezzo, Ancona, and Florence."



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0h Universal time on the respective dates.

Mercury reaches greatest western elongation on August 5th, 19° from the sun. It can be seen low in the eastern sky before sunrise about a week before and two weeks after that date. The planet then becomes lost in the solar glare, superior conjunction occurring on the 31st.

Venus in midmonth sets about $\frac{3}{4}$ hour after the sun, but may be glimpsed just above the western horizon after sunset because it is so bright — magnitude −3.3. Observers with binoculars may be able to see the close configuration of Venus and the $1\frac{1}{2}$-day-old moon on August 23rd. Conjunction in right ascension occurs at 22^h Universal time, with Venus 1° north as seen from the center of the earth. The planet will be occulted in Antarctica. Earlier in the month, on the 8th at 14^h UT, Venus will pass 1° north of 1st-magnitude Regulus; however, this event will be very difficult to observe.

Mars rises shortly before midnight, local time, in the middle of August, and can be viewed in central Taurus as an object of magnitude +0.7. In a telescope, Mars' small gibbous disk is seen, 87-per-cent illuminated and 7".1 in diameter. The moon will be near Mars on the morning of the 15th, and two days later the planet will pass 5° north of Aldebaran.

Jupiter is very prominent in Ophiuchus, crossing the meridian about an hour after sunset on the 15th and setting around midnight. The giant planet's magnitude is −2.0, and a telescope will show its disk, 42".5 in equatorial diameter and 39".7 in polar. Jupiter is stationary in right ascension on the 20th, resuming direct (eastward) motion among the stars. The moon will pass 5° north of Jupiter on the morning of the 3rd, and again on the evening of August 30-31.

Saturn is east of Jupiter in the sky, in Sagittarius, and crosses the meridian about two hours after sunset, being well placed for observation in the southwestern sky during the evening hours. Its magnitude is +0.4. In a telescope the disk is seen, 16".1 in polar diameter, as well as the famous ring system, 40".6 across and widely opened. The moon will be near Saturn on August 4-5, and again on the night of the 31st.

Uranus is in conjunction with the sun on August 14th, and thus invisible all month.

Neptune is an 8th-magnitude object near the Libra-Virgo border this month. It crosses the meridian about two hours before sunset in mid-August, and may be seen with small telescopes low in the southwestern sky during the early evening hours. The chart on page 191 of the January, 1960, issue, will aid in finding this faint object.

W. H. G.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours, respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.

VARIABLE STAR MAXIMA

August 1, R Bootis, 143227, 7.2; 6, R Draconis, 163266, 7.6; 8, R Normae, 1528**49**, 7.2; 11, R Sagittarii, 1910**19**, 7.3; 13, R Ursae Majoris, 103769, 7.5; 13, W Ceti, 2357**15**, 7.6; 16, RT Cygni, 194048, 7.3; 23, S Virginis, 1327**06**, 7.0; 24, S Carinae, 1006**61**, 5.7; 31, RT Sagittarii, 2011**39**, 7.0.

September 3, W Lyrae, 181136, 7.9; 5, U Cygni, 201647, 7.2; 8, T Camelopardalis, 043065, 8.0.

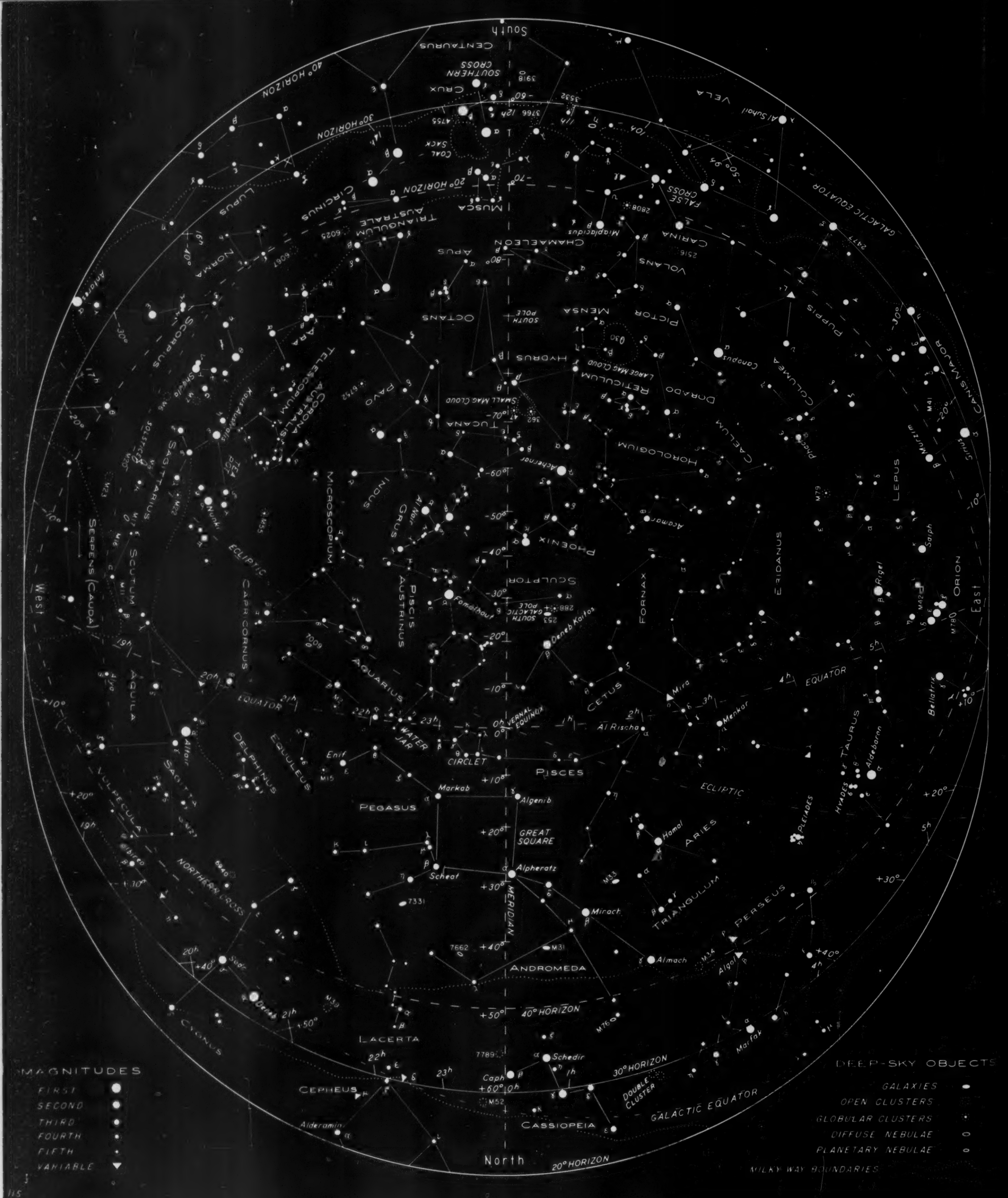
These predictions of variable star maxima are by the AAVSO. Only stars are included brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

MINOR PLANET PREDICTIONS

Julia, 89, 9.5. August 24, 23:44.9 +17-01. September 3, 23:36.0 +18-23; 13, 23:25.3 +19-13; 23, 23:14.3 +19-31. October 3, 23:04.6 +19-20; 13, 22:57.5 +18-51. Opposition on September 13th.

Io, 85, 10.4. August 24, 23:58.2 +12-27. September 3, 23:53.6 +11-20; 13, 23:47.5 +9-45; 23, 23:40.8 +7-51. October 3, 23:34.7 +5-48; 13, 23:30.2 +3-51. Opposition on September 18th.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.



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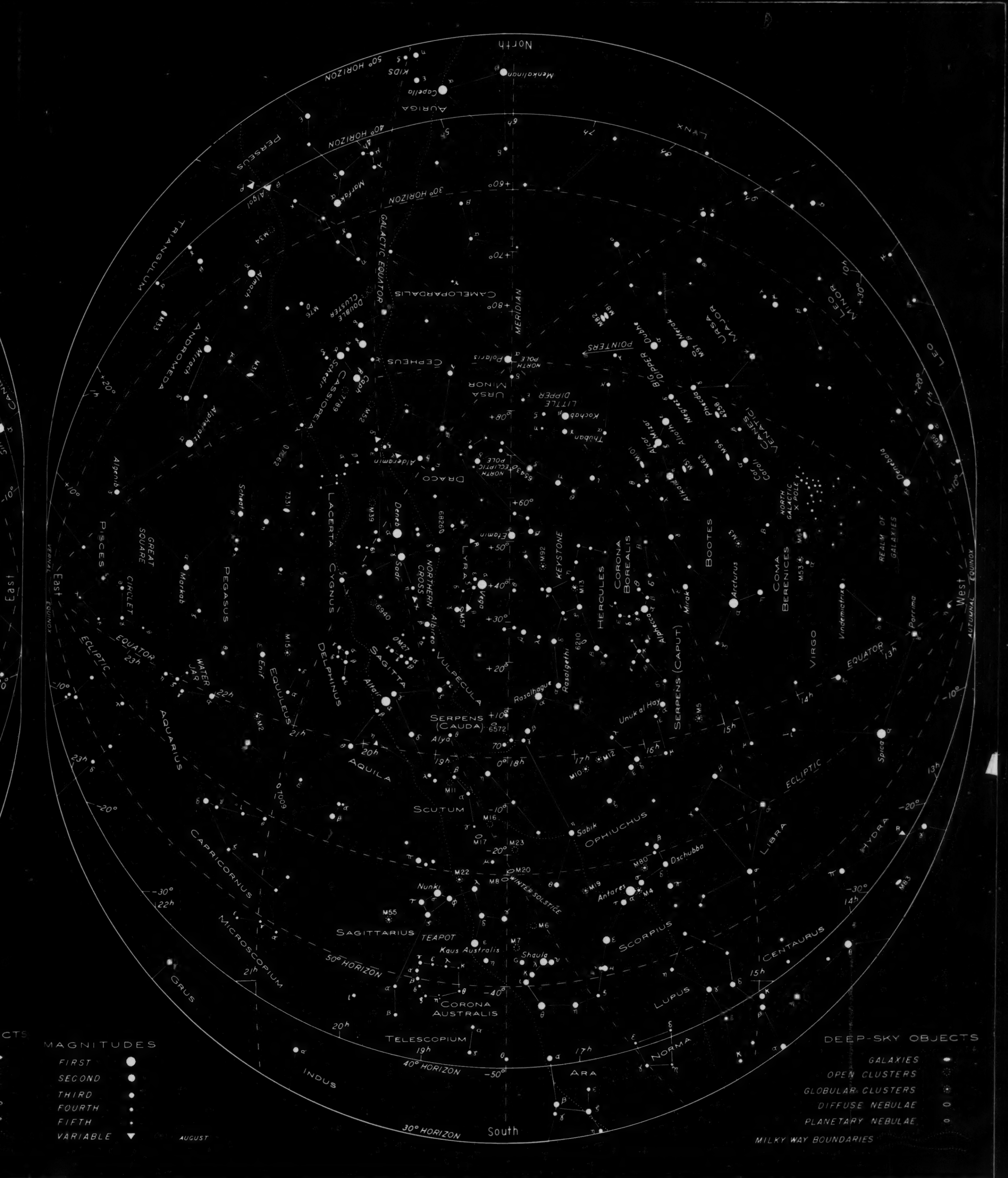
SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 6th and 22nd of October; also, at 9 p.m. and 8 p.m. on November 6th and 21st. For other dates, add or subtract ½ hour per week.

When facing south, hold "South" at the bottom; turn the chart correspondingly for observing in other directions. Near the south celestial pole the Small Magellanic Cloud, a neighbor galaxy, is well placed for observation, while Pegasus dominates the northern sky.



STARS FOR AUGUST

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 6th and 22nd of August, respectively; also, at 7 p.m. on September 6th. For other dates, add or subtract ½ hour per week.

The head of Draco is at the meridian, making identification of this winding constellation particularly easy this month. To the south the sky is ablaze with the starclouds of the Milky Way. Note especially Scutum and Scorpius, rich sights in binoculars.

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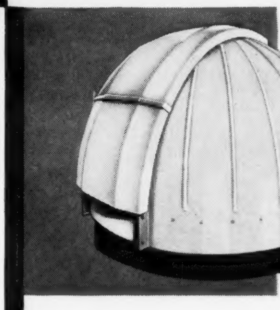

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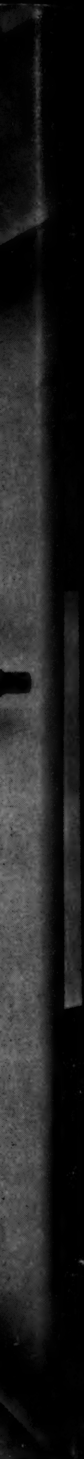

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